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JPRS-JST-87-009

3 APRIL 1987

Japan Report

SCIENCE AND TECHNOLOGY

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JAPAN REPORT

SCIENCE AND TECHNOLOGY

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'ASTRO-C' SATELLITE LAUNCH SET FOR 5 FEB

OW010639 Tokyo KYODO in English 0621 GMT 1 Feb 87

[Text] Tokyo, Feb. 1 KYODO--Japan will launch a satellite this Thursday, which is expected to be monitored by amateur and expert astronomers, whose mission will be to pursue unknown celestial objects, especially so-called black holes and neutron stars that are the last aftermaths of matured stars, the Education Ministry's Space Science Institute said.

The satellite, "Astro-c," is the third x-ray astronomical satellite to be launched by the Education Ministry's Space Science Institute from its space observatory in Kagoshima in southern Japan.

It is equipped with state-of-the-art devices jointly developed by Japan and Britain, including one that can observe x-ray intensities of up to one-1,000th of a second radiated by permanent stars during their evolutionary process, the institute said.

The satellite's astronomical survey will especially focus on X-1 in the Cygnus (Swan) and the Quasar 3c273 which are considered to be evolving into black holes or to have a large black hole in its center, it said.

Offers have come from many foreign astronomists for joint astronomical observations with the Astro-c, Minoru Oda, director of the institute said.

The satellite, which is square, pillar-shaped and measures a meter wide and 1.55 meters high, is the heaviest scientific orbiter in Japan, weighing 420 kilograms, the institute said.

The satellite will orbit the earth from a height of 600 kilometers after being launched with a M3S2-type rocket, it said.

/9716
CSO: 4307/014

FEASIBILITY STUDY PLANNED FOR PASSENGER PLANE

OW290951 Tokyo KYODO in English 0942 GMT 29 Jan 87

[Text] Tokyo, Jan 29 KYODO--Three major Japanese aircraft makers have agreed on starting in early February a feasibility study on joint development of an airliner capable of carrying about 100 people, an industry association disclosed Thursday.

The Society of Japanese Aerospace Companies (SJAC) said that directors of the three firms will meet every two months to study over the next one year marketing strategy, concept for the new model and technical aspects.

The three makers are Mitsubishi Heavy Industries Ltd., Kawasaki Heavy Industries Ltd. and Fuji Heavy Industries Ltd.

At the same time, Japanese makers of aircraft parts will send their managers to a joint working group and subcommittees, it said.

The feasibility study will be also participated in by the Japan Aircraft Development Corp. (JADC) and the International Aircraft Development Fund (IADF) that funnels funds for such development, it said.

If all goes well, it may lead to a major international joint project along with "v2500" aeroengines now being developed by a five-nation consortium including Japan and the United States, and "YXX/7j7," a medium-range commercial aircraft being promoted by Boeing Co. of the United States and the three Japanese aircraft makers, it added.

Japanese, U.S. and European aircraft makers are now targeting the development of small passenger planes for medium and short range use.

Specifically, Messerschmitt-Bolkow-Blohm GMBH (MBB), the largest West German aircraft maker, and China Aero-technology Import and Export Corp. (CATIC) have sounded out Japanese counterparts on the possibility of participation in development of "MPC 75," a 75 to 100-seat plane, jointly promoted by them.

In addition, the Indonesian Government has also made a similar inquiry to the Japanese counterparts on possible participation in "Atra 90," a 90-seat plane planned by Indonesia.

There is even a possibility that Indonesia would join the yxx/7j7 program, the society said.

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BRIEFS

ASTRO-C SATELLITE LAUNCHED--Uchinoura, Kagoshima Pref., Feb. 5 KYODO--Scientists at the Kagoshima Space Center Thursday launched the Astro-c satellite, an x-ray monitoring craft that is expected to make a major contribution to astronomical science. The 420-kilogram Astro-c, developed by the Education Ministry's Institute of Space and Astronautical Science (ISAS), will serve as a probe to search for neutron stars and black holes, the existence of which have yet to be confirmed by scientists. The satellite, third in the Astro series developed for scientific purposes, will orbit some 530 kilometers above earth in a 600-kilometer circumference outfitted with British and Japanese-developed x-ray and gamma-ray monitoring equipment. ISAS officials pointed out that the Astro-c becomes the only x-ray satellite of its kind in orbit at present, and one that is expected to serve the interests of the international community. Space centers officials confirmed that the Astro-c satellite entered low-earth orbit as scheduled at 3:36 p.m., six minutes after liftoff. [Text] [Tokyo KYODO in English 0654 GMT 5 Feb 87 OW]

MARINE OBSERVATION SATELLITE LAUNCH--Tokyo, Feb. 17 KYODO--Japan's National Space Development Agency (NSDA) said Tuesday that the launching of the country's first marine observation satellite, MOS-1, is expected to proceed on schedule Wednesday morning at the Tanegashima Space Center in Kagoshima Prefecture. If successfully launched, the experimental satellite will orbit some 900 kilometers above sea level to observe oceanic conditions and collect data on climatic conditions, pollution, and natural disasters, NSDA officials said. Although the United States and France have launched similar observation satellites in the past, the MOS-1 is expected to provide the first detailed information of its kind on oceanographic conditions, data that will also be relayed to the European Space Agency (ESA) and Australia. The 740-kilogram MOS-1, measuring 1.3 meters in width and 1.5 meters in length, is equipped with sensor equipment capable of picking up microwave and infrared rays. It will relay information gathered from special ocean buoys and its earth station. Information processing is expected to enter full-scale use by next fall at NSDA's earth station in Saitama Prefecture. [Text] [Tokyo KYODO in English 0856 GMT 17 Feb 87 OW]

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CSO: 4307/014

DEVELOPMENT OF HERPES SIMPLEX VACCINE BY rDNA TECHNOLOGY

Tokyo BIO INDUSTRY in Japanese Oct 86 pp 15-22

[Article by Chikateru Nozaki and Hiroshi Nakatake, Molecular Genetics Laboratory, Chemical and Serotherapy Research Institute, Foundation]

[Text] Since herpes simplex virus involves complication such as cryptogenic infection and carcinogenesis, research is being concentrated to develop component vaccines by recombinant DNA technique rather than conventional attenuated or inactivated vaccines. In this paper, the developmental research being conducted in the author's laboratory on herpes simplex vaccine with yeast cells as hosts will be explained.

1. Introduction

Herpes viruses infecting humans include herpes simplex virus (HSV), chickenpox, herpes zoster, and Epstine-Barr virus. Among them, infectious diseases by HSV are on the increase year by year. These infectious diseases are characterized by the cryptogenic settlement of the virus in sensory ganglia after infection. Latent viruses are induced to manifest lesions after being provoked by various factors (such as stresses, traumas, drugs, UV rays, etc.). The reason why infectious diseases by HSV have recently taken a sharp increase may be ascribed to the fact that once people were immunized through slight infection in infancy, but recent improvements of circumstances in life reduced this chance as well as the extension in scope and mode of sexual behaviors.

Currently, chemotherapy and inoculation of vaccines are under consideration for controlling infectious diseases by HSV. Most of the antiherpes agents are nucleotide analogs, which inhibit DNA synthesis as antimetabolites; acyclovir among these agents was found to be effective against infectious diseases due to HSV. Therapy is confined to the alleviation of symptoms; the drug neither erradicates latent viruses nor completely inhibits their activation.

Turning to the control of HSV by vaccine, Skinner reported efficacy of a subunit vaccine in inhibiting occurrences of herpes in sexual organs. This vaccine was prepared by infecting cultured human cells with HSV and letting viruses multiplicate. These types of vaccines are always fraught with the danger of contamination by infectious viruses or extra DNAs. Since the

Table 1. Infectious Diseases Caused by HSV

1. Initial infection type
   a. Inapparent infection
   b. Manifest infection
      (1) Herpes labialis, gingivostomatitis
      (2) Rhinitis, pharyngolaryngitis, tonsillitis, tracheobronchitis, pneumonia, neuralgia
      (3) Felom caused by herpes
      (4) Traumatic herpes
      (5) Keratoconjunctivitis caused by herpes
      (6) Esophagitis caused by herpes, hepatitis
      (7) Genital herpes
      (8) Encephalitis, myelitis, neuritis
      (9) Neonatal herpes
      (10) Abortion, stillbirth, teratosis
2. Recurrent infection type
      (1) Cutaneomuscus lesions such as herpes labialis
      (2) Keratoconjunctivitis caused by herpes
      (3) Genital herpes
      (4) Lesions in central nervous system such as encephalitis

possibility cannot be ruled out that HSV may be involved in carcinogenesis, whether or not such genetic substances are included in vaccine preparations become critical problems.

To circumvent these problems of vaccine preparations from tissue cultures, we attempted the development of a herpes simplex vaccine by means of recombinant DNA technique.

2. HSV

HSVs are spherical bodies with an outside diameter of 120-150 nm, consisting of envelope, tegument, capsid, and core (from outside to inside (Figure 1).

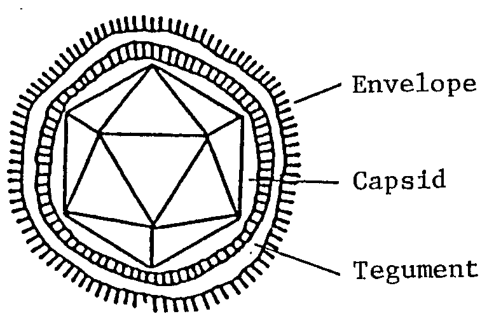

Figure 1. Schematic Diagram of HSV

There are primarily 4 glycoproteins (gB, gC, gD, and gE in the order of decreasing MW) in the envelope, each with immunogenicity. HSVs are classified into type-1 and type-2. Among 4 glycoproteins, gB and gD have epitopes in common with both types of viruses. In particular gB is a component necessary when the virus particle invades host cells, contributing to the fusion of envelope and host cell membranes as well as to the fusion of infected cells, i.e., the formation of macrocells. Also, the anti gB antibody causes complement dependent lysis of injected cells and has an HSV-neutralizing activity.

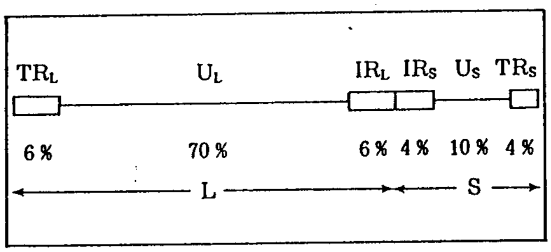

Figure 2. Structure of HSV DNA

Unique U_L and U_S regions are flanked by inverted repeats, TR_L/IR_S and TR_S/IR_S, at both ends.

The core is a spherical complex of DNA and protein with a diameter of 30 nm (Figure 2). HSV DNAs are linear double strands of 150 KB consisting of L-region and S-region that give rise to 4 equivalent amounts of isomers depending on the difference in the order of two regions in each strand.

3. Cloning of gB Genes

Since glycoprotein gB purified from viruses can prevent the infection of both HSV-1 and HSV-2, the gB gene product was selected as the target of our recombinant vaccine.

Firstly, cloning of the gB gene and its analysis was conducted. HSV-1 (KOS strain) infected cultured cells (Vero) and was subjected to proliferation. The virus DNA was extracted and purified. Cloning of XhoI-BamHI DNA fragment (3.5 Kb) corresponding to map unit 0.345-0.368 which was already reported to contain gB genes was conducted and the sequence of nucleotides was determined. Allocation at only one place was possible to the open reading frame coding for gB (903 amino acids) because of its size. When the sequence was compared with that of B_2ik, they differ at four positions in terms of nucleotides and at one position in terms of amino acids. A part of the gene is shown in Figure 3.

Figure 4 depicts the results of hydrophilicity-hydrophobicity analysis of peptides expected from nucleotide sequences. Pellett proposed a three-dimensional structure model of gB fused with the cell membrane. According to that model, gB consists of a signal domain necessary for passing through the membrane, external domain protruding outside, membrane spanning domain, and an internal domain intruding into cytoplasm.

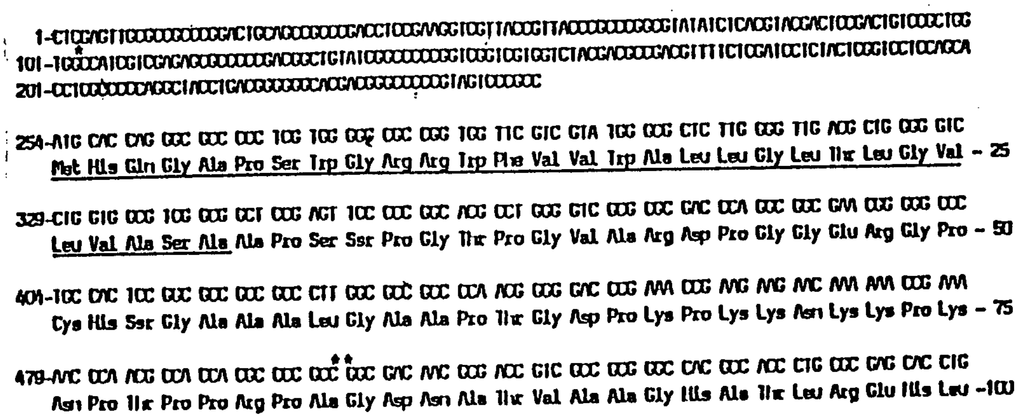

Figure 3. Nucleotide Sequence of gB (Partial) and Amino Acid Sequence

The sequence underscored constitutes the signal domain (estimated). Figures at the left ends of the sequence denote nucleotide numbers from XhoI site, while figures at the right ends denote amino acid numbers.
* BalI site; ** NaeI site

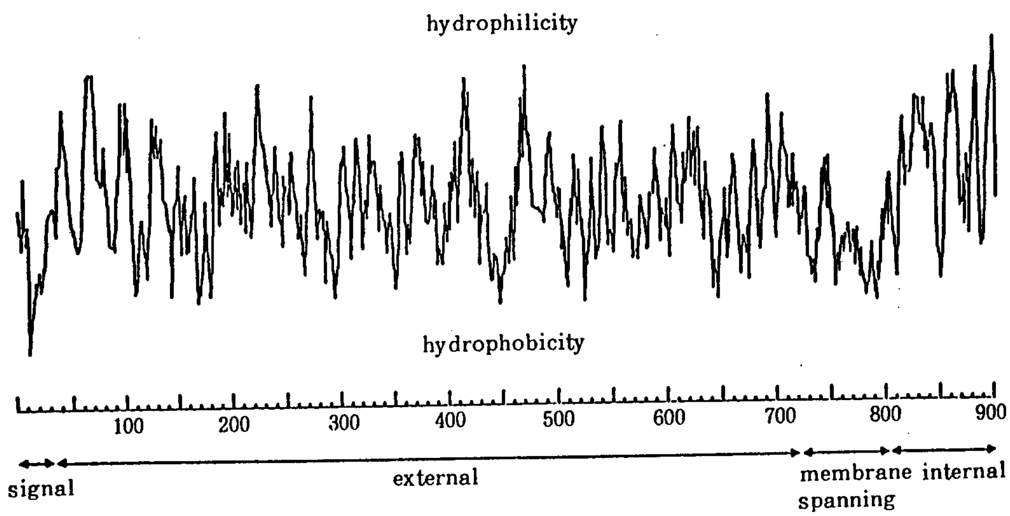

Figure 4. Hydrophilic-Hydrophobic Profile of gB

The higher the upward peaks, the stronger the hydrophilicity. Figures denote the number of amino acids from N-terminus.

4. Expression of gB Gene by Yeast

Yeast appears to be a suitable host for producing strongly hydrophobic proteins like those of the virus envelope. For example, yeast is far superior to E. coli in production efficiency of expressing surface antigen genes of beta-type hepatitis virus. Therefore, the first use of yeast was made at the expression site of the gB gene.

4.1 Construction of Plasmid for Expression

The shuttle vector used was PAM 82 which is capable of replicating in both the yeast and E. coli (Figure 5). In this vector, there are ars 1 gene and 2μ ori gene necessary for replication in yeast, and leu 2 gene as a selected marker. In addition to these, there is a repressible acid phosphatase promoter derived from yeast. Induction of this promoter can be controlled by the concentration of phosphate in the medium.

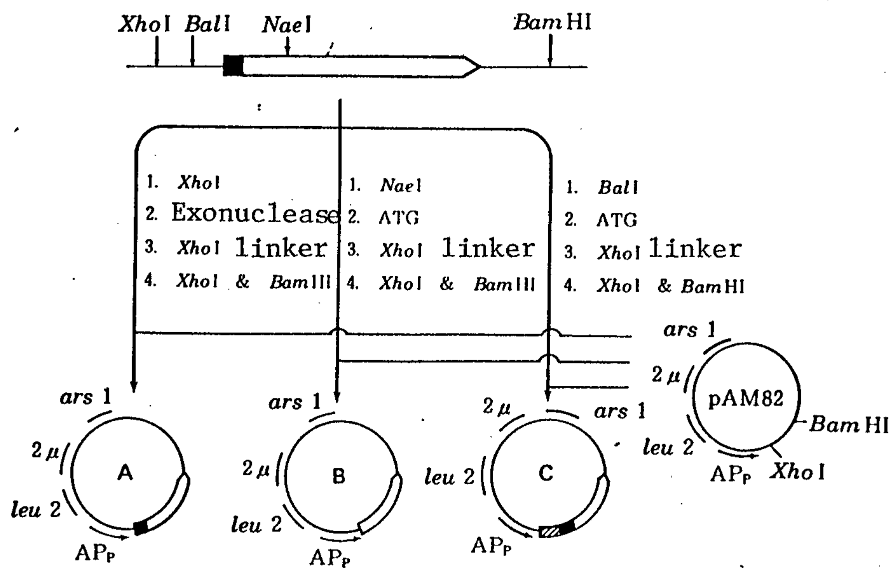

Figure 5. Construction of the Plasmid for Expression of gB
: gB structural gene, : signal domain, : regions coding for amino acids to be attached to the upstream of gB-N-terminus, ATG: synthetic nucleotide having the initiation codon in accordance with the gB gene frame. APp: repressible acid phosphatase promoter. Yeast provided with plasmid B or C produces gB.

We inserted gB gene cloned this time into the downstream of the promoter. The design was made so that the distance between the promoter and the gB structural gene becomes comparable to the original distance between the promoter and the phosphatase structural gene by deleting 5'-nontranslational regions with exonuclease (Figure 5A).

The plasmid constructed in this way was introduced into yeast and transformants that grew in the medium deficient in leucine were screened. The transformants selected were further transferred to the medium without phosphate to cancel the repression of the repressible acid phosphatase promoter. Thus the induction of gB gene expression was attempted, however, gB could be detected neither in culture media nor in mycellia by means of enzyme linked immunosorbent assay (ELISA).

4.2 Expression by the Removal of the Signal Region

Then it was decided to remove the domain coding for signal sequence followed by connection to the phosphatase promoter (Figure 5B). That is to say, the translation initiation codon was artificially linked in accordance with the reading frame of the remaining structural gene after the segment containing the signal domain was removed from gB gene with restriction enzymes and the resultant combined gene was inserted into a downstream position of the phosphatase promoter of PAM 82. The transformed yeast with its plasmids was induced to produce gB in a fashion similar to that described above. Consequently, the production of gB came to be recognized in mycellia (Table 2).

Table 2. Production of gB by Yeast

Host	Plasmid	Induction	gB(ng/mℓ)
AH 22	B	+	510
	pAM 82	−	< 1
AH 22 pho 80	B	+	350
	pAM 82	−	330

In yeast, aH22, repressible acid phosphatase promoter can be induced depending on the concentration of phosphate in the culture media. Yeast, AH22 pho 80, is a mutant invariably released from the repression in the promoter. Mycellia were treated with Zymolyase-60,000 to give spheroplast before being broken into fragments with Triton X-100 and measured by ELISA method for gB.

Since gB production depends on the induction with manipulation of phosphate in culture media, gB gene plasmid is obviously said to be under the control of repressible acid phosphatase. Also, if mutant invariably released from repression by the repressive acid phosphatase is used, the production of gB becomes possible without induction. Such hosts are not subjected to serious growth inhibition even when producing gB.

Such a big fluctuation in the gene expression depending on the presence or absence of the signal region is also reported for gene coding in the growth hormone. The amount expressed increased 25 fold if the signal region was deleted for the expression of growth hormone genes in yeasts.

4.3 Expression After the Addition of Polypeptide at the N Terminal Position

Next, the effect of polypeptide additions at the upstream position of the signal region instead of removing the region was investigated. Design was made so that the additional 55 amino acids could be added to the N-terminal position of gBN by artificially inserting the initiation codon, ATG, at the 5' nontranslational region in accordance with the reading frame of gB gene (Figure 5C). Yeast transformed with these plasmids showed the productivity of gB to an extent similar to that when the signal region was eliminated.

It is an interesting phenomenon that gBN·N-terminal sequence exerts a great influence on the expression, constituting an important factor for the increase in expression.

5. Analysis of Yeast gB

5.1 Effect of Yeast Protease

To investigate the property of gB (YgB), the attempt was made to purify it from mycellia. The source used for the purification was the expression production of gB genes from which the signal region was eliminated.

Since gB is a strongly hydrophobic protein, the addition of a surfactant (1 percent Triton X-100) is necessary for the extraction of gB from yeast mycellia. In the presence of such surfactants, chromatographies over hydroxyapalite or Con A lectin were effective for partial purification. Further chromatography over monoclonal antibody column gave gB higher purity, which was used for the following experiments. Figure 6 shows the results of silver staining or immunoblot of YgB after being subjected to SDS-PAGE. Three bands having gB antigenicity are detected. (M.W. 94K, 89K, 50K). These molecules are smaller in size than that expected for the expression product. Therefore, the influence of the yeast protease on the product was suspected.

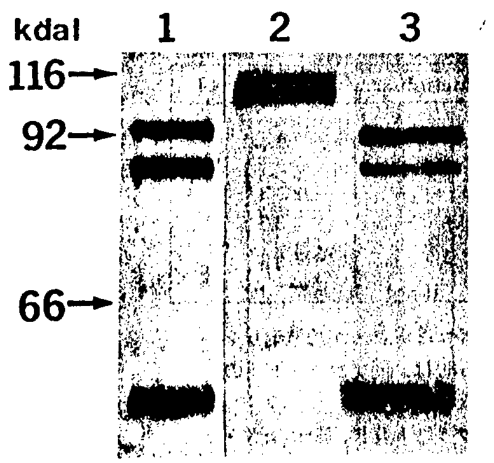

Figure 6. SDS-PAGE Analysis of gB

1: Silver staining of YgB
2,3: YgB, VgB were subjected respectively to western blot and then reacted with anti-gB-antibody followed by secondary antibody for color-development (immunoblot).

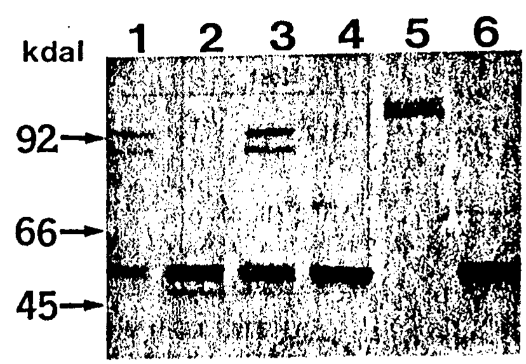

Figure 7. Influence of Protease on gB

1: YgB
2: YgB + yeast extract liquid
3: YgB + yeast extract liquid + PMSF
4: YgB + Forsecin-Y_1
5: VgB
6: VgB + yeast extract liquid

Each sample was subjected to SDS-PAGE and then to immunoblot.

When YgB or virus gB reacted with yeast extract to confirm this, convergence occurred at 50K band and the reaction was blocked by protease inhibitors (PMSF) (Figure 7). Also, cleavage position of gB by forcesin Y-1, a protease extracted and purified from yeast, was investigated and was found to be localized on one-half of the peptide chain (Figure 8). Indeed it was found that YgB converged to antigenic 50K by forcesin Y-1.

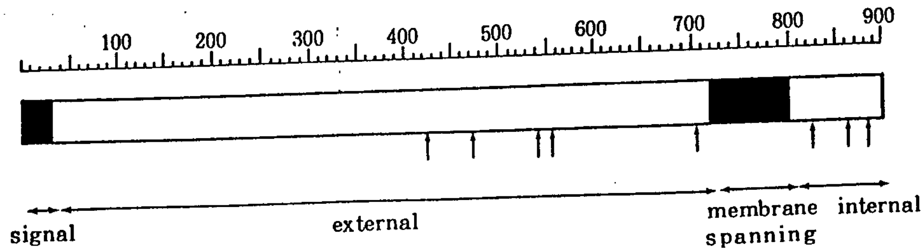

Figure 8. Cleavage Sites of gB by Forcesin Y-1

Cleavage sites of gB by Forcesin Y-1 (Arg-Arg, Arg-Lys, Lys-Lys) are indicated with an arrow. ■ denotes a particularly strong hydrophobic region; upper numbers indicate numbers of amino acids from N-terminus of gB.

Amino acid analyses are currently being conducted on YgB per each molecular weight. The result will make possible the analysis of gB in terms of epitope as well as the expression of a specified region in terms of gene level.

5.2 Sugar Chain of Yeast gB

The occurrence of mannose type was anticipated since it was found that YgB was adsorbed on Con A lectin during the purification process. Therefore, the cleavage pattern by endoglycosidase H was examined and the results are shown in Figure 9. According to that, YgB was found to have a sugar chain of 6K.

The availability of sugar chains in the exogenous gene expression product by yeast have also been reported for surface antigens of influenza virus. Such addition of sugar constitutes one of the advantages of yeast which E. coli does not afford.

5.3 Antigenicity of Yeast gB

Next, antigenicity of YgB which is very important was investigated and the result was shown in Table 3. When YgB was administered to guinea pigs, the antibody titer value and neutralization activity were investigated. YgB was found to have activity comparable to that of YgB. Further it was found that when mice inoculated with YgB were exposed to HSV-1 or HSV-2, the infection by either type of virus was prevented.

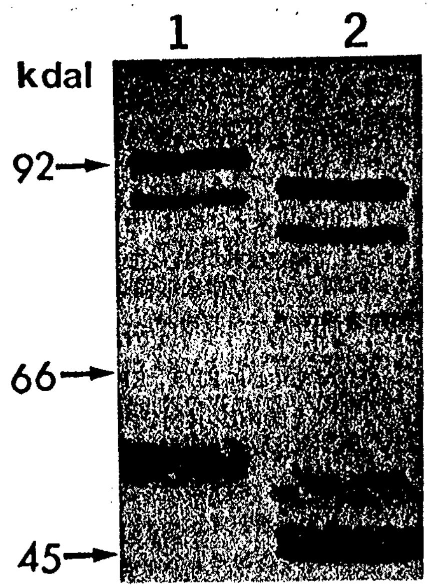

Figure 9. Endoglycosidase H. Treatment of gB

1: YgB
2: YgB + endoglycosidase H. Samples were subjected to SDS-PAGE followed by immunoblot after being reated at 37°C for 4 hours.

Table 3. Antigenicity of Yeast gB

Guinea pig	1 week after 3rd injection		1 week after 4th injection	
	ELISA[a]	Neutralizing[b]	ELISA[a]	Neutralizing[b]
1	0.12	2	0.30	16
2	0.18	4	0.33	16
3	0.17	4	0.29	16
4	0.17	4	0.37	32
5	0.15	2	0.24	8
Control[c]	0.08		0.07	

a ELISA antibody titer, absorbance at 492 nm
b Neutralizing activity, dilutions for the inhibition of the plaque formation of the virus
c Guinea pigs inoculated with the yeast extract which does not produce gB

6. Concluding Remarks

Since gB produced by yeast has a sugar chain as well as antigenicity properties against both HSV-1 and HSV-2 as does virus gB, it is provided with sufficient capabilities for the herpes simplex vaccine. In this paper the expression of gB gene with yeast as the host cell has been described. We have also succeeded in the expression of the gB gene using cultured animal

cells as the hosts. In that case, the expression product accumulates in cultured cells when the gB gene is intact. It also becomes possible to let the product excrete in the medium by removing the strongly hydrophobic membrane spanning region from the gB gene.

Which gB is most suitable for vaccine, produced yeast, cultured cells, or any other cells as host, must await further research.

This paper describes the results of cooperative research of both a molecular genetics laboratory and a virus laboratory, Chemical and Serotherapy Research Institute (a foundation). On closing, the authors wish to express their deep appreciation to Prof Kenichi Matsubara, Cell Technology Center, Osaka University for his many pieces of advice.

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20138/9365
CSO: 4306/3672

POLYMERIC DESIGN FOR MEDICAL ENGINEERING DESCRIBED

Tokyo NIKKO MATERIALS in Japanese Aug 86 pp 32-36

[Article by Toshihiro Akaike: "Hybrid Medical Engineering Materials Are Studied; Biospecificity Materials Are Expected To Contribute to Medical Engineering as Well as Life Engineering"]

[Text] 1. Preface

It is anticipated that in the 21st century, human society qualitative betterment will be made through improved welfare and innovation in production activities. One of the relevant areas expected to make great progress in the future is a new area between material engineering and life phenomena--life engineering. Materials have contributed to medical engineering and biotechnology which are two mainstays that support life engineering, while expectations for new materials by designers are likely to increase. In this article, individual roles played by polymeric materials in medical engineering and biotechnology are to be discussed and the necessity and importance of the material design fusion in individual areas are to be described.

2. Themes of Polymeric Design for Medical Engineering

Hybrid Medical Engineering Materials

Reproduction of highly sophisticated functions possessed by bioelements such as protein, cells and organic tissues is a great dream of chemists and material engineering scientists as well as bioscientists. The challenge to this dream is made chiefly from two concepts. Figure 1 is a summary of these two approaches by using the hierarchical nature of biotissues; i.e., they can be largely divided into an artificial approach which realizes all functions from molecular to cellular to tissue in terms of synthetic chemistry and an approach by combining effectively utilized bioconstituents with the advantages of artificial materials. The former system can be compared to biomimetic engineering, while the latter can be referred to as a hybrid approach since it uses hybridization of artificial materials and organisms or, in a broader sense, biofunction application engineering.

Organic materials represented by high polymers have contributed greatly to biomimetic engineering. The pursuit of artificial enzymes, artificial enzyme carriers (hemoglobin), artificial antigens (vaccine), and artificial

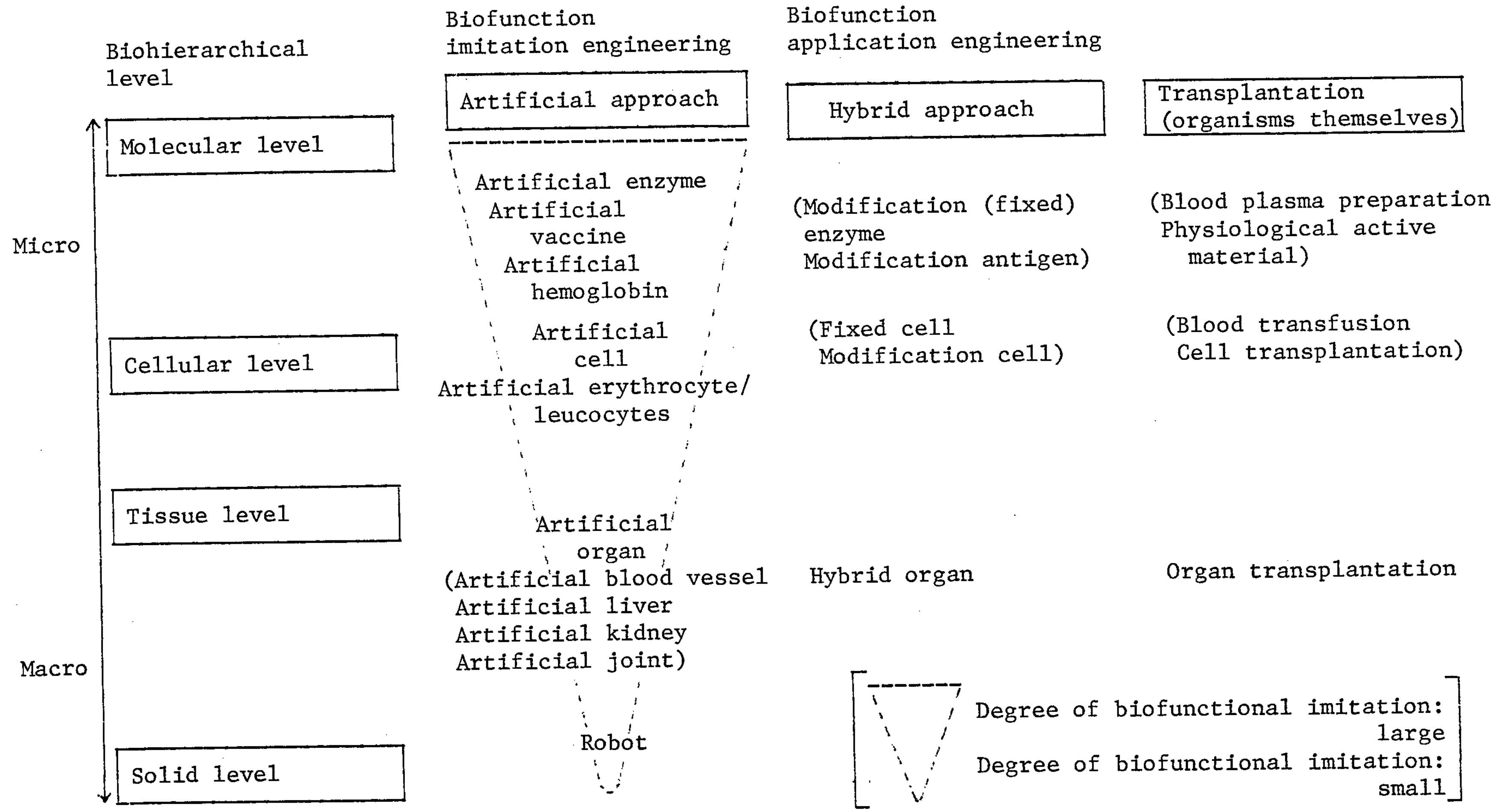


Figure 1. Pursuit (Imitation and Application) of Biofunctionality in Medical Material Design

ion carriers aimed at molecular-level bioimitation has evolved in many nations, led by Japan as molecular design work for organic materials themselves. In addition, research into artificial cells is being energetically conducted in the designing of individual artificial organ functions and in the pursuit of target directional drug delivery systems (missile drug).

For critical organic (tissue) diseases, organ (tissue) transplantation, besides functional substitution by artificial organs, is considered to be an effective means. The development of immune histocompatible repressors for organ replantation has been underway recently while such barriers emerge as increased communicable diseases and limited available organs, so that great expectations are placed on artificial organs especially in Japan.

Artificial organs are divided into two--those implanted in a body to be used semipermanently such as artificial blood vessels and joints, pacemakers and artificial cardiac valves and those for short term use with their main frames or parts outside of a body, such as an artificial kidney, liver, heart, and lung. Built-in types of the former are not perfect in their biofunctionality and bioadaptability, so that artificial blood vessels and cardiac valves and many others are used only for limited cases under strict conditions. Therefore, increased performance is expected with increased use.

On the other hand, functions of waste processing organs such as the kidney as well as metabolic, endocrine organs such as the liver and pancreas are maintained as extremely fine multiphase systems, so that it is impossible under present circumstances to substitute them completely by artificial materials.

In short, efforts are being made at present to raise the level of mimetic technology for artificial biofunctions to a higher level, from molecular to cellular, tissues (organ) and solids, while in reality, the higher the level of mimetic technology, the lower the degree of mimetic. Hence, "hybridization" which is under experimentation involves combining and fixing cells and proteins which are responsible for organism functions, with and to artificial materials and thereby depending upon these constituents for high-standard parts and responsible functions (Figure 1).

Let us consider cellular-level hybridization, taking the "liver" as an example. The liver, the largest chemical plant in an organism provides a number of metabolic functions led by sugar metabolism through synthesis and decomposition of glycogen, synthesis, decomposition and secretion of hematic proteins, lipid metabolism, urea synthesis, bilirubin discharge, and antidotal function. The liver is an organ with an active regeneration ability so that complete hepatic function substitution for a mere week or so for patients suffering from a number of chronic and acute hepatic diseases such as, hepatic cancer, liver cirrhosis and fluminant hepatitis, is possible and can be expected to contribute to their survival to a considerable extent in combination with surgical and internal treatments. At present, a hepatic function auxiliary device called an artificial liver merely substitutes for the antidotal function, one function of the liver, by the activated carbon adsorption method.

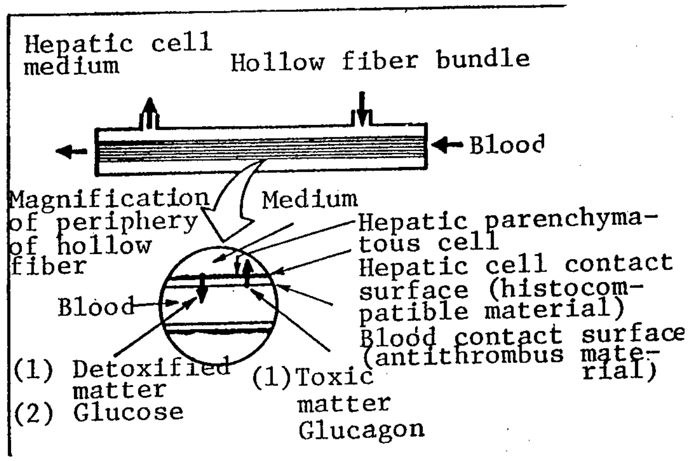
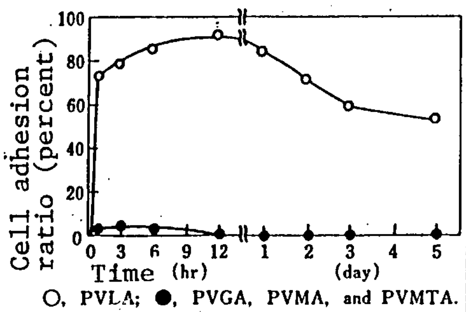


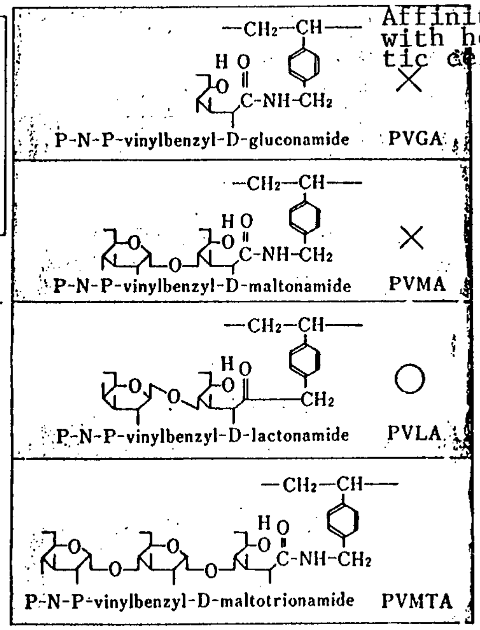
Figure 2. Material Design in Hybrid Type Artificial Liver

In this context, it follows that hepatic cells themselves which are responsible for the hepatic function in an organism are cultured and fixed on an artificial material and depend upon these bioconstituents for a highly sophisticated part of their function. Figure 2 shows the most general concept of a hollow fiber type artificial hepatic system. Hepatic cells on the outside of hollow fibers take in through their walls toxic materials and drugs in the blood and excrete them into the blood after their antidotal treatment. They also detect hormones in the blood such as glucagon and insulin, perform glycogen metabolism in response to them and discharge or take in glucose (adjustment of blood sugar values). Hepatic cells must perform the above mentioned functions according to material information in the blood, so that the hollow fiber surface of the cells that need histocompatibility in order for hepatic cells to adhere stably and multiply can function. On the other hand, permeability and high antithrombotic properties are required for materials in contact with blood.

A team, including the author, has found that collagen extracted from an oxide has excellent adhering characteristics to hepatic cells and function maintenance, as well as analyzing their mechanisms. This material surpasses the ordinary material (polystyrene for cell culture) in adhering hepatic cells both in the absence as well as presence of serum. We have also found that polystyrene (Figure 3(A)) having lactose as its side-chain is one of a few hepatic cell synthetic adhesive materials (Figure 3(B)). It is extremely interesting that hepatic parenchymatous cells recognize and adhere to lactose (its end is galactose) alone among the polystyrene derivatives with sugar side-chains of different structure as well as a number of plastic materials (in Figure 3(A); good adhesion and poor adhesion are shown by O and X marks, respectively).

Such a unique adhesive cell material is indispensable for the development of hybrid type artificial organs, while at the same time, its importance is beginning to be recognized from another point of view. For example, much of drug metabolism is performed in hepatic parenchymatous cells. An





↑ Figure 3(B). Adhesion Ratio Durability of Hepatic Parenchymatous Cell to Individual Polystyrene Derivatives

(WE culture medium including 10 percent cow fetal serum is used.)

↑Figure 3(A). Polystyrene Derivatives With Various Sugar Side-Chains

(Good affinity and poor affinity with hepatic parenchymatous cells are shown by O and X marks, respectively.)

excellent simulation model (biosimulation) to analyze antidotal metabolic reactions to drugs which is indispensable for developing medicines, too, has an extremely close relationship with the design of an artificial liver. In this case, too, a material which ensures long-term adhesion of hepatic cells is important. In addition, the establishment of a hepatic cell mass culture system will pave the way for mass pharmaceutical preparation of blood plasmas such as albumin and various coagulation factors.

As has been pointed out, the pursuit of an artificial liver results in, at the same time, repercussions in medicine designs and the mass production of various physiologically active materials. In this sense, it can be said that the fusion of research with artificial organs (research into medical engineering materials) and so-called biotechnology is inevitable.

3. Biotechnology Expectations for High Polymer Design

A number of polymeric materials have recently advanced into the fields which apparently seem to be least relational to them, such as gene recombination technology and cell fusion and culture, thereby supporting their rapid evolution. Figure 4 shows a flow of useful material production processes by the

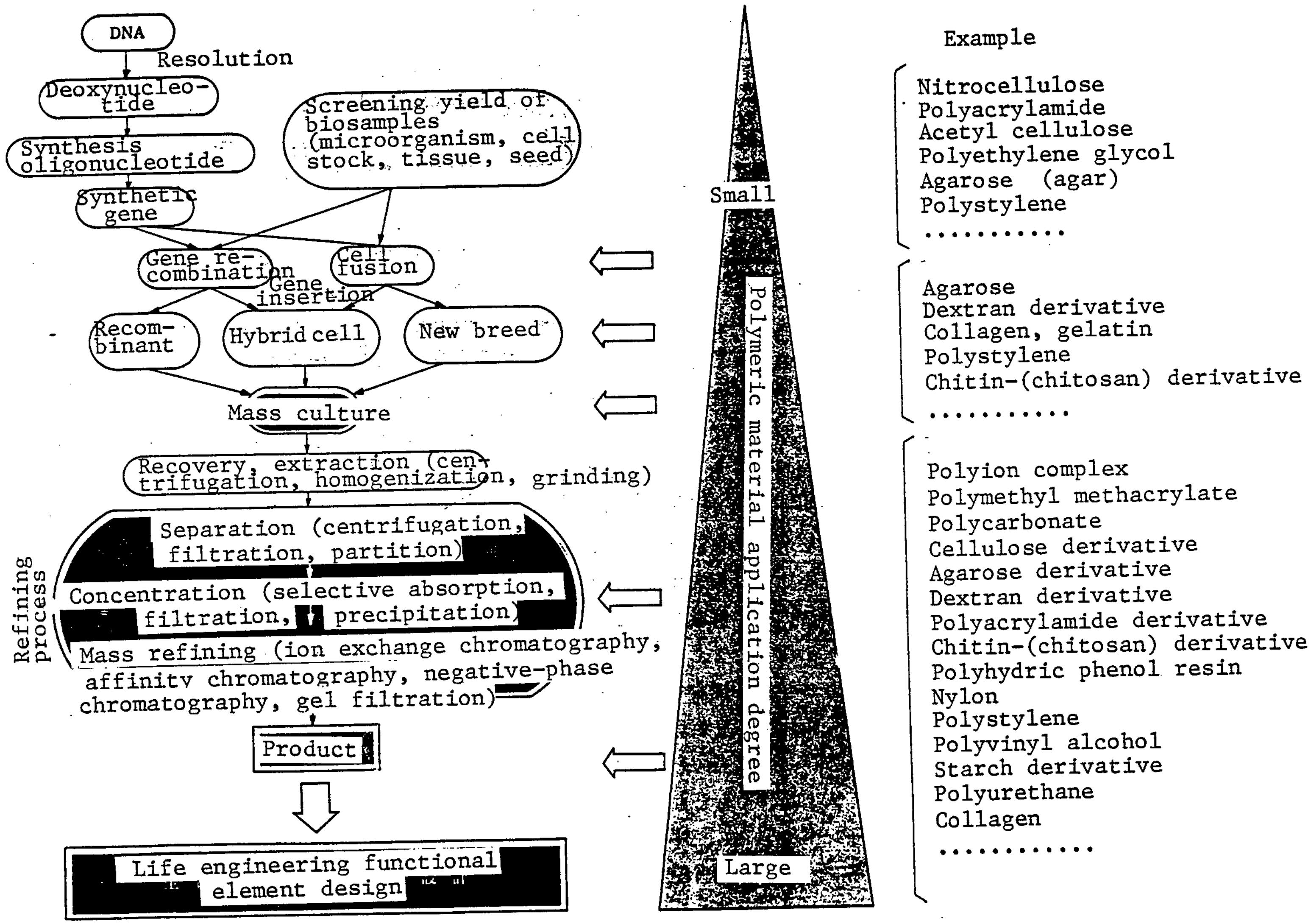


Figure 4. Production of Useful Materials by Genetic Engineering and Cytoengineering and Their Applications
--Roles Played by Polymeric Materials--

most typical genetic engineering and cytoengineering technologies and a role played by polymeric materials. For example, for production by the coli-bacillus-gene recombination method of physiologically active protein such as insulin, interferon, interleukin growth factors, tissue plus (minogen) activators, etc., materials such as nitrocellulose, polyacrylamide and polystyrene derivatives are indispensable in extraction, synthesis, refining and analysis of various upstream nucleic acid constituents. Agarose, polyethylene glycol, etc., are essential in cell fusion technology, isolation, and collection of various cells.

For cloning, separation, and culture operations for various midstream recombinants, syncytiums and new breeds, polystyrene, collagen, dextran derivatives and chitin-(chitosan) with a different choice of materials for different type cells are used.

In the downstream area, separation and refining of products such as proteins, antibiotics, amino acids, etc., are performed by mass culture of various cells. This process uses an array of polymeric materials with their number exceeding those of the other two areas (see downstream area in Figure 4). Imagine the separation/refining processes by the most popular column chromatography: ion exchange chromatography, various adsorption chromatographies, negative-phase chromatography, gel filtration, and various affinity chromatographies utilizing a key-key hole relation unique to organisms--they are all technologies themselves utilizing polymeric materials. Separation/refining technologies utilizing films are the same as above.

Various high polymers from the upstream to midstream to downstream areas are utilized; however, the author should stress in this chapter that these are never the complete, best choice for molecular design. Exactly speaking, it may be said that they are merely a choice by a biotechnology expert from among ordinary materials. For this point, the history of the development of medical engineering materials and materials for artificial organs among others, will be a good guide. Initially, diversion of industrial materials was made on a trial-and-error basis and proper materials were selected (first generation). In the next phase, transformation from the primary to higher-order structures was conducted based on the molecular frames of the aforementioned materials and material characteristics were additionally improved (second generation). Recently, the pursuit of molecular/material design has been made based on data accumulated in these processes, resulting in the creation of materials with excellent bioadaptability and biofunctionality (third generation). It is anticipated that molecular and material design of biotechnology materials will undergo the same processes as above, and in any event, judging from the magnitude of their repercussions and the size of their market scale, they are likely to be more important themes than medical engineering materials.

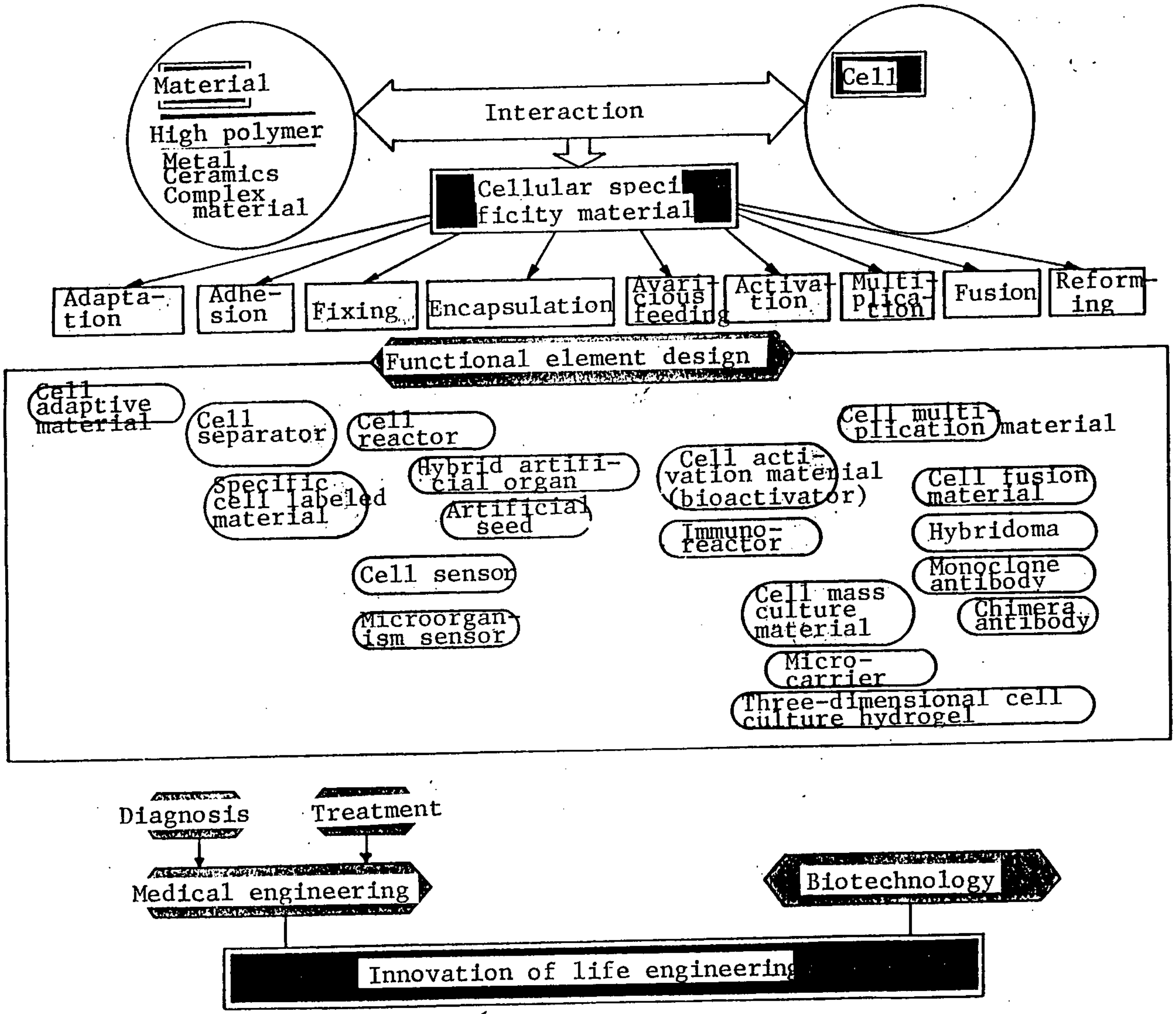


Figure 5. Development of Cellular Specific Polymeric Materials and Innovation of Life Engineering

4. Conclusion

Fusion of Medical Engineering Material Studies and Biotechnology

In closing, let me stress once again that the material development in the medical engineering sector stated in chapter 2 is approaching very close to biotechnology materials. Medical engineering materials are designed on the premise that they come in contact mainly with biotissues and it is an important problem to control interaction between materials and individual hierarchies of biomolecules, cells, and organs, which construct biotissues, which coincide with the target for biotechnology materials. Figure 5 shows repercussions on the life engiheering sector when interaction between materials and

various cells is controlled by material design which results in the manifestation of their specificity. It shows that the effective, amplified manifestation of various cellular functions permits a remarkably great number of biofunctional elements to be designed. This almost applies to the design of biomolecular specificity materials which control their interaction and biomolecules represented by protein and extract their specificity.

These biospecific materials are expected to contribute to the innovation of life engineering including biotechnology as well as medical engineering. It may be no longer too far to say that the progress of medical engineering materials will result in their fusion with the mainstream of biotechnology, further leading to the innovation of life engineering.

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SUPERCRITICAL FLUID EXTRACTION, APPLICABILITY EXAMINED

Tokyo BIO INDUSTRY in Japanese Aug 86 pp 60-67

[Text] Supercritical fluid has characteristics which cannot be seen in any other solvents. By using supercritical fluid as a solvent, new processes for separation have been studied in various areas. Principles and applicability are introduced in this report.

1. What Is Supercritical Fluid?

1.1 Critical Temperature, Critical Point

Although gas dissolving nonvolatile materials cannot be experienced in daily life, this phenomenon has long been observed. High-pressure steam under the ground will dissolve nonvolatile materials containing salts, and it is sometimes observed that the feathers of a high-pressure steam turbine are damaged by the adhesion of organic salts. The reason why gas dissolves nonvolatile materialsis that Van der Waals force works between molecules.

When steam is compressed, it is generally liquefied at a certain pressure. This phenomenon occurs because the shortened distance between molecules induces the molecules to coagulate and form a coagulated state that is energetically stable. This effect is called the coagulation effect. This coagulation force differs with the kind of molecules, and, therefore, some liquids dissolve materials, while others do not. When the coagulation force of a solvent and a solute are approximately equal, the energy difference before and after mixing is negligible, and, therefore, it is natural that molecules distribute at random and mix well. On the other hand, some solvents dissolve the solute only partially. This is because the difference in their coagulation force is large; the coagulation of the same kind of molecules is more energetically stable than the random distribution. For this reason, it has long been said that similar materials mix well.

The force that disperses molecules randomly is molecular thermal energy. Since the ordinary gas has a large distance between molecules, the coagulation effect is negligible, and molecules tend to disperse anywhere in the air. This is known as the diffusion effect. The diffusion effect increases with temperature, while the coagulation effect depends on density rather than temperature. Therefore, all substances turn to gas with the rise of temperature, and are affected by the coagulation effect with the rise of pressure. At a point where the coagulation effect balances with the diffusion effect, gas and liquid coexist.

However, as the size of the coagulation effect is limited, the diffusion effect always predominates, and the gas never liquefies when the temperature rises up to a certain point, even if the average distance between molecules is small and molecules contact each other. This temperature is called the critical temperature. When a gas is compressed at a temperature, the compression rate becomes infinite at a certain pressure, and a very small increase in pressure increases the density of a gas. The point where the compression rate becomes infinite is the critical point, the terminal point of the liquid-gas equilibrium line.

Every substance has an intrinsic coagulation effect, and the critical point is also intrinsic to a substance. Table 1 shows the critical points of some substances. Because of the hydrogen bond, water has a large coagulation force, and shows an extraordinarily high critical temperature in comparison with its molecular weight.

Table 1. Critical Properties of Substances

Solvent	Critical properties		
	Temperature (°C)	Pressure (atm)	Density (g/cm^3)
Methane	−83	45.4	0.16
Ethylene	9	49.7	0.22
Chlorotrifluoromethane	29	38.7	0.58
Carbon dioxide	31	72.8	0.47
Ethane	32	48.2	0.20
Nitrous oxide	36	71.5	0.45
Sulfur hexafluoride	45	37.1	0.74
Propylene	92	45.6	0.23
Propane	97	41.9	0.22
Ammonia	132	111.3	0.24
Trichlorofluoromethane	198	43.5	0.55
n-Hexane	234	29.3	0.23
Isopropanol	235	47.0	0.27
Ethanol	243	63.0	0.28
Toluene	318	40.6	0.29
Water	374	217.7	0.32

1.2 Supercritical Fluid

Supercritical fluid, the main topic of this report, is high-density fluid with a temperature and pressure higher than its own critical point, which has the same coagulation force as liquid but is always predominant in the diffusion effect, and its density can be continuously converted with a change in pressure and temperature. Table 2 shows the density, diffusion coefficient, and viscosity of some supercritical fluids in comparison with ordinary gases and liquids.

Table 2. Physical Properties of Gas, Liquid, and Supercritical Fluid

Physical properties	Phases		
	Gas	Supercritical fluid (SCF)	Liquid
Density (g/cm^3)	$(0.6 - 2.0) \times 10^{-3}$	$0.2 - 0.9$	$0.6 - 1.6$
Diffusion coefficient (cm^3/s)	$0.1 - 0.4$	$(0.2 - 0.7) \times 10^{-3}$	$(0.2 - 2.0) \times 10^{-5}$
Viscosity (cp)	$(1 - 3) \times 10^{-2}$	$(1 - 9) \times 10^{-2}$	$0.2 - 3.0$

As you can see from this table, the supercritical fluid has the same density (coagulation effect) as ordinary liquids, while the transporting properties like the diffusion coefficient and viscosity are very close to those of gases. As reported previously, since the coagulation effect is the main factor of the dissolution force, the supercritical fluid has the same dissolution force as a liquid and its extent can be continuously converted with density. Moreover, the transporting properties are very near to a gas; thus, it has properties never found in traditional liquid solvents.

2. Principle of Supercritical Fluid Extraction

The extraction of the supercritical fluid is a separation process under high pressure in which the compressed, high-density supercritical fluid is used as a solvent in place of liquid. Its characteristics originate from supercritical fluid properties; its dissolving ability can be changed continuously by pressure and temperature.

The dissolving ability dependency on temperature and pressure is subject to density change, and as reported before, the fluid is very easily compressed near the critical point, the extraction processes are generally performed near the critical point of the solvent; it is convenient to carry out at $0.9 < Tr < 1.2$ and $1 < Pr < 2$, Tr and Pr show the reducing temperature (T/Tc) and the reducing pressure (P/Pc), respectively, which are obtained by dividing T or P by the value of the solvent's critical point.

2.1 Solubility of Supercritical Fluid

Figure 1 shows the solubility of a nonvolatile gas in the supercritical fluid under various pressures and at two different temperatures which are near the critical temperature. The longitudinal axis indicates the actual concentration in the supercritical fluid phase instead of the ordinary mole fraction. If you consider the extraction process, the concentration in the extraction phase is more valuable than the mole fraction, as it is the basic data for estimating the equipment volume directly. However, it is difficult on many occasions to measure the density of each phase in the equilibrium state under high pressure, and therefore sometimes only the data with mole fraction is available.

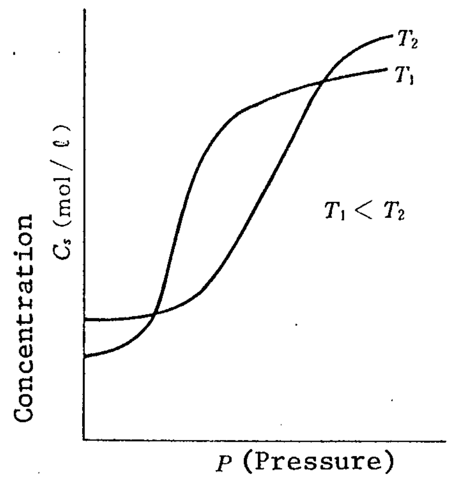

Figure 1. Concentration and Pressure of Solute in Supercritical Fluid

In Figure 1, the gas phase is considered similar to the ideal gas in the lower pressure area, the solute concentration is restricted by the vapor pressure and it is approximately constant. The concentration of solute increases rapidly with pressure, and then becomes constant. This rapid increase is induced by the large coagulation effect brought in response to the rapid increase in the solvent density near the critical point, while the approximately constant solubility is brought about because the solvent molecules coagulate densely, become noncompressive, and the extent of the coagulation effect is limited.

The solubility temperature dependency is apparently complicated, in the low pressure area, the evaporation of solute is enhanced by the temperature rise, and the concentration of solute in the vapor increases. On the other hand, under medium pressure the temperature rise reduces solubility, and the solute condenses. This phenomenon which cannot be experienced ordinarily is called reverse condensation. It occurs because the decrease in solvent density increases with the rise of temperature, and because the diffusion effect of solute disappears because solubility depends on the coagulation effect, while in high pressure areas where the coagulation effect is limited, the solubility changes with the size of the vapor pressure because the diffusion effect of the solute reappears.

As previously reported, the coagulation effect has a correlation with density, and solubility changes proportionally with the vapor pressure of a solute, if compared under equal density. Such solubility density dependency is very effective for qualitative measurement of solubility under various temperatures and pressures. However, it is very difficult to set density as a direct operational variant. As shown in Figure 1, to understand the dependency of solubility on temperature, and pressure is very important.

The solubility of target materials in supercritical fluid depends on the affinity between solvent and solute. In a carbon dioxide-naphthalene system, at 35°C with less than 200 atoms, whose concentration of naphthalene is 10^4 times as high as the value expected from its vapor pressure. In some systems, solubility increases by 10^{10} times.

2.2 Process of Supercritical Fluid Extraction

Figure 2 shows the outline of the supercritical fluid extraction. In the system in Figure 2, raw materials and extraction residues are continuously supplied and ejected, and supercritical fluid is circulated several times.

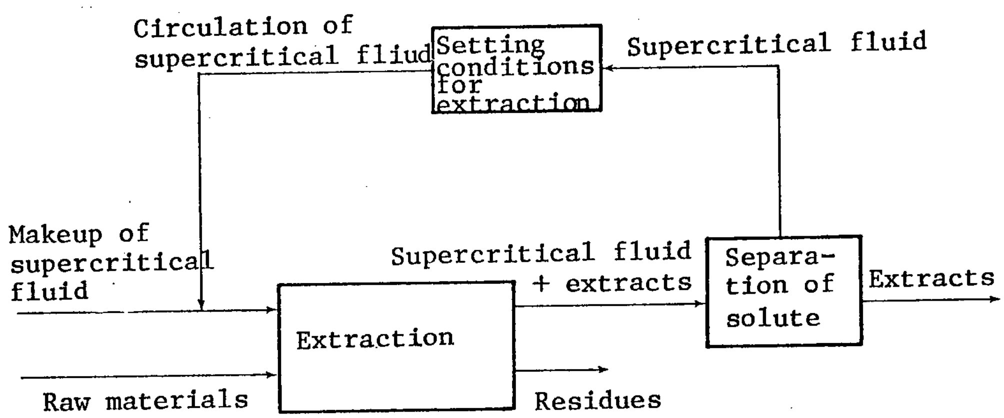

Figure 2. Outline of Process of Supercritical Fluid Extraction

In the extraction process, supercritical fluid contacts raw materials to move target materials into the supercritical fluid phase. When raw materials and extraction residues are liquid, the continuous supply to the high-pressure facility is considerably easy. However, when materials or residues are solid, a continuous operation is fairly difficult, and the supply and ejection of materials must be carried out by the batch process, in some cases according to the amount of materials to be treated. In this case, it is desirable to shorten the time required for supply and ejection. (Wade) Corporation's open-close method with a high pressure vessel performs the process within 1 minute and is an excellent method. In bulk treatment, if the time required for compression and decompression is taken into consideration, a continuous operation would be advantageous; therefore, establishing a technique for stable supply and ejection of solids is very desirable.

The separation of solute from the extraction phase is easily carried out with reduced pressure. The extent of pressure-reduction is very important if recompression cost is taken into account. It might be necessary to introduce a dynamo-recovering facility like an expansion turbine. On the other hand, it is possible to decompress in several steps to fractionate the solute into several components. In principle, by reflux of the liquid, rectification will become effective; in this case, the problem is to transport the liquid to a high pressure area. It might be effective to use decompression energy for transportation.

When the solvent is repeatedly circulated, it is not always necessary to separate the solute completely, as it is possible to separate most of the solute by heating, according to the principle of reverse condensation shown in Figure 1. In this case, rectification is also carried out easily by setting appropriate temperature gradients at the solute separation area, and by refluxing the condensed liquid by making use of density differences. The change in temperature and pressure can also be used simultaneously, furthermore, absorption and adsorption could be employed.

At operation temperatures, the solvent is a gas, and, therefore, the remainder of solvent in the extract and the residue will be made extremely small, but total recovery is difficult. For this reason, the makeup of solvent gases will be needed.

3. Characteristics of Supercritical Fluid Extraction

Supercritical fluid extraction is considered, in the low pressure area as distillation with inactive gases such as steam distillation, while in the high pressure area, as liquid extraction since it makes use of the solvent effect based on coagulation force.

(1) Comparison With Steam Distillation

Steam distillation is a method to separate contents at high boiling points, where steam serves to elevate the entire pressure of the system and to enhance the contact between gas and liquid. It is not different from vacuum distillation in the equilibrium theory. Therefore, in order to treat a considerable amount, it must be performed at a high temperature in order to heighten the steam pressure of the solute, and a large-volume facility is also necessary as the solute concentration is low in the gas phase.

On the other hand, in the supercritical fluid extraction, an inactive gas with its critical point near operation temperature is employed, and the pressure of the inactive gas is raised, which has the same effect as raising the operation temperature in order to heighten the solute steam pressure in the vacuum distillation. In this case, of course, intermolecular action between the solvent and the solute is used, and so the effect depends on the kind of gases. When a proper gas is chosen, it has the same effect as when the operation was carried out with the steam pressure as high as 10^4 - 10^{10} times; and materials with considerably low steam pressure can be separated with smaller facilities.

(2) Comparison With Liquid Extraction

The liquid extraction and the supercritical fluid extraction can be directly compared with each other under a certain condition where the extraction temperature is raised above the critical temperature, with the solvent density maintained at constant. In this case, the rise in temperature increases the diffusion effect of the solute (steam pressure or sublimation pressure), while the coagulation force of the solvent does not change if the density is constant; for this reason, the solvent ability is higher in the supercritical state. However, an extremely high pressure is required to

maintain density at a constant value in a considerably wide temperature area, and density-reduction to a certain extent should be allowed. Moreover, the reverse phenomenon shown in Figure 1 will be found in some cases.

Furthermore, the operation temperature is restricted to maintain thermal stability of the solute, therefore, to compare at a certain operation temperature is important for practical applications. In this comparison, the kind of extraction solvent is different between the two methods. When the extraction temperature is restricted at near room temperature, it is very difficult to find a supercritical fluid-solvent dissolving high-polar solute and materials with high molecular weights. This is because the supercritical fluid used has to be limited to one with low-molecular weight, low-polar materials. It is much easier in the case of liquid solvents.

(3) Advantages and Disadvantages of Separation Processes

Previously, the supercritical fluid extraction was compared with the traditional distillation or liquid extraction focused on the ability to dissolve materials. The supercritical fluid extraction has the following characteristics in regard to the operation processes compared with the traditional methods.

A. In the liquid extraction, mixed solvents have to be used or large-scale temperature change is required for selective separation of extracts containing more than two materials. For this reason, this method is not applicable to the industrial-scale operations. While, in the supercritical fluid extraction, the extracts can be fractionated easily by the change in temperature and pressure.

B. In the liquid extraction, distillation or stripping is necessary for separating the solvent from the extract or the residue, and even though these operations are performed, complete separation will be difficult. In the supercritical fluid extraction, the extract and the residue are easily and completely separated by returning the pressure to normal.

C. Generally, in liquid extraction, the complete separation of the extraction phase from the residue phase is difficult, but in supercritical fluid extraction, the separation of the two phases is easy, as the density differences are large, and the viscosity of the extraction phase is low; the entrainment of solid particles and liquid drops can be eliminated.

D. Compared with liquid extraction, the speed to move materials and to permeate the materials to be extracted is higher in the supercritical fluid extraction.

All the above characteristics can be surmised from the supercritical fluid properties reported earlier. Following are the disadvantages:

A. When the operation temperature is limited to a certain extent, the choice of solvents for various materials is not easy, as few fluids have their critical temperatures near operation temperatures.

B. This method uses high-pressure facilities and its initial cost is very high; moreover, appendix facilities are required for safety measures.

4. Application Areas

Table 3 shows the major areas where supercritical fluid extraction is used. All of them make use of some properties of the supercritical fluid. They have one or more advantages, such as the rise of product value, the separation of materials which cannot be separated by traditional methods, the simplification of separation and refinery processing, and the reduction of utility cost.

(1) Supercritical Carbon Dioxide

Supercritical carbon dioxide has its critical temperature at 31°C, near room temperature. It is nontoxic, noncombustible, and cheap. Because of these properties, it is very suitable as a solvent for biochemical materials and foods which require treatment under moderate conditions. It dissolves simple lipids (triglycerides, wax) and induced lipids (fatty acids, carotinoids, steroids, terpenoids). However, it is not a suitable solvent for complex lipids (phospholipids, sugar lipids). Various alkaloids in plants containing pharmacological substances can be extracted by supercritical carbon dioxide. On the other hand, sugars and amino acids are almost insoluble even when treated at 40°C, under 2,000 bar; thus materials having strong polarity are considered insoluble in supercritical carbon dioxide.

As reported above, supercritical carbon dioxide extracts selectively nonpolar materials or materials with weak polarity; for instance, edible oil is extracted with simplified processes, and its quality is improved. Nicotine from tobacco leaves and caffeine from coffee beans can also be extracted by making use of the selectivity of supercritical carbon dioxide.

(2) Denicotinization of Tobacco

Figure 3 is a diagram of the extraction of nicotine from tobacco. Supercritical carbon dioxide dissolves aromatic compounds as well as nicotine. As shown in Figure 3, first, aromatic compounds are extracted, then nicotine is extracted. Alkaloids like nicotine increase their solubility by adding water as an entrainer. By returning extracted aromatic compounds to denicotinized tobacco, mild, fragrant tobacco can be produced. If it is done by liquid extraction, aromatic compounds and nicotine are not easily separated, and the fragrance is reduced. This process uses the property of the supercritical gas wisely.

(3) Fractionation of Fatty Acids

Further, supercritical carbon dioxide extraction is applied to the fractionation of fatty acids and their monoesters which are obtained by hydrolysis or ester-exchange of mixed triglycerides.

The natural fatty-acid mixtures are straight-chain mixtures, saturated or unsaturated fatty acids with carbon atoms from 12 to 14. Eisenbach showed

Table 3. Application Examples of Supercritical Fluid Extraction

Natural products, foods

- Decaffeine from coffee and tea
- Deodorization of fats and oils
- Denicotinization of tobacco
- Extraction of plant oil from seeds
- Extraction of edible pigments from plants
- Extraction of seasoning, flavor, and perfume
- Extraction of hop and spice
- Extraction of lanolin from wool
- Extraction of pharmacological substances from plants
- Removal of fats and oils from snacks, such as potato chips

Separation of chemical materials from natural resources

- Separation of alcohol from biomass
- Fractionation of fatty acids consisting of natural fats and oils

Treatment of heavy hydrocarbons

- Deasphaltation from fractionated petroleum
- Regeneration of waste oil and waste lubricant
- Liquefying coal
- Extraction of oil shell, tar sand, and lignite
- Treatment of nonvolatile oil
- Extraction of mineral wax
- Fractionation and refining of heavy oils

Separation and purification of chemical substances

- Separation of organic oxides from water
- Separation of aromatic and fatty hydrocarbons
- Separation of nonpolar substances from polar substances
- Separation of aromatic homologues
- Separation of isotopes
- Purification of organic metal compounds

Geophysics

- Explanation of phenomena induced by actions of the supercritical fluid

Removal of solids from high-viscosity fluids

Tertiary recovery of crude oil

Treatment of polymers

- Extraction of solvents, monomers, and oligomers from polymers
- Fractionation of polymers

Extraction of drinking water from sea water

Regeneration of active carbon, adsorbents, filters, and catalysts

Supercritical fluid chromatography

Production of fine particles by deposition from the supercritical fluid

[continued]

[Continuation of Table 3]

Deposition of substances in ultrafine pores
Chemical reactions
Extraction of carboxylic acids from water
Enzyme reactions
Production of methylethyl keton
High-temperature, high-pressure reactions
Drying at critical point
Drying of biological tissues
Drying of aerogel

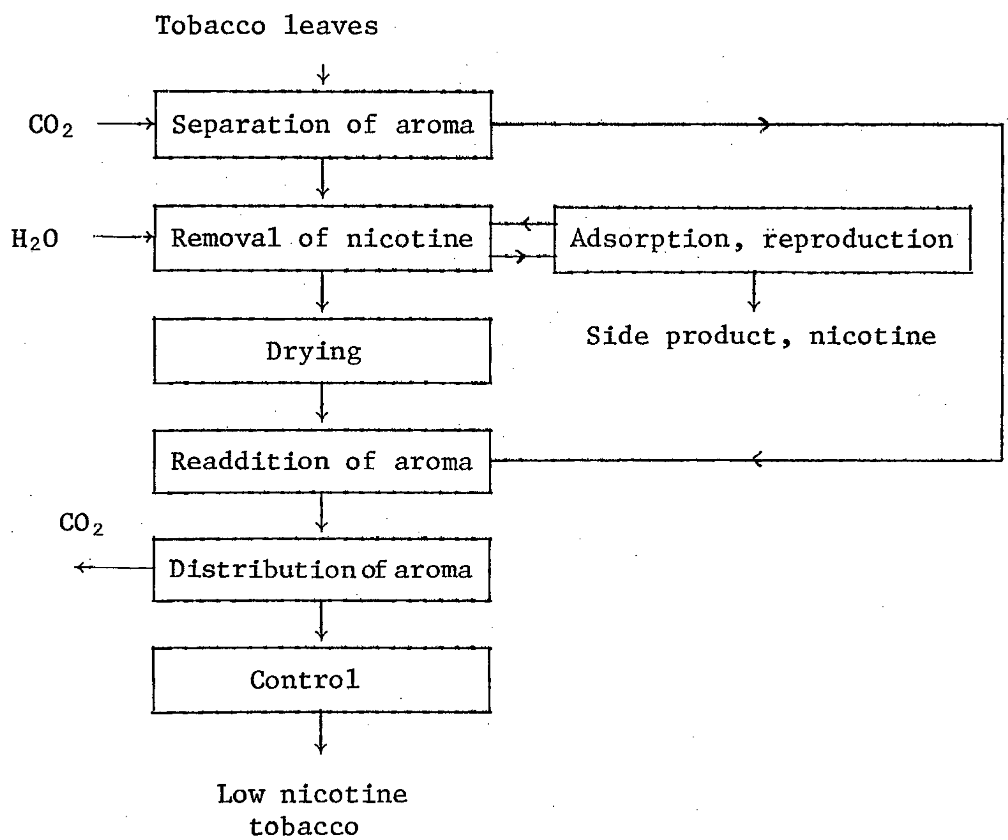

Figure 3. Extraction Process of Nicotine From Tobacco by Supercritical Carbon Dioxide

the possibility of fractionation with the difference in carbon atom numbers by using semibatch rectification facilities with a refluxer, the heater being set at the top of the tower. By this method, it is difficult to separate unsaturated fatty acids with the same carbon number but different number of

double bonds. In our laboratory, the method to identify in supercritical carbon dioxide the difference in the number of double bonds was studied, and as a result, it was found that urea and deoxycholic acid make inclusion compounds with fatty acids selectively according to the degree of unsaturation, just as in general liquid solvents. If this principle is used, the extraction processes will be simplified compared with the traditional urea-added fractionation method.

(4) Treatment of Heavy Hydrocarbons

The application of supercritical fluid extraction in the treatment of heavy hydrocarbons is a typical example where the permeation and selective dissolution, which occurs according to the difference in molecular weight, of the supercritical fluid are used. This treatment reduces the viscosity and density of the extraction phase, and the amount of solid materials dissolved in it will become extremely small. Also, in other application examples, the properties of the supercritical fluid are well used, and future development is highly expected.

5. Problems and Future Prospects

In recent years, the supercritical fluid extraction has been drawing attention, but very few commercial plants have been built; they include the fractionation of heavy hydrocarbons, deasphalting, extraction of caffeine from coffee, and extraction of hops. The examples shown in Table 3 have no technical problems and the running costs are smaller than the traditional methods in most cases. The largest disadvantage is that the initial cost is very high as high-pressure facilities have to be used, and in addition, there is no information for judging whether the high costs can be covered by energy saved through this method. The increase of information for scale-up, and solving the technical problems which are confronted when solid materials are treated in high-pressure facilities is desirable. Therefore, in addition to the present studies focused on screening, other studies such as the study on phase-equilibrium necessary for designing facilities, and the study of the speed to move materials should be conducted.

As reported above, the supercritical fluid extraction has excellent characteristics in principle, and it will establish industrially a position as a unit-treatment in the future. Furthermore, the supercritical fluid has begun to be used for adsorption and absorption, as well as extraction of solvents, and further development is expected.

The addition of an entrainer has proved to be effective in changing the dissolving ability and selectivity of the supercritical fluid. In addition, the idea to use the supercritical fluid as a cosolvent of liquid solvents is very interesting, as the pressure change easily controls the constituents' ratios.

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20140/9365
CSO: 4306/3655

PROJECT FOR ADVANCES IN UTILIZATION OF NEW ELECTRONIC COMPUTERS

Tokyo DENSHI KOGYO GEPPO in Japanese No 4, 1986 pp 10-16

[Article by Electronics Policy Division, Machinery and Information Industries Bureau, MITI]

[Text] Following the report of the Data Processing Promotion Council (directed by Shohachi Hanai, counselor, Toyota Motor Corp.), the new "Program for Advances in the Utilization of Electronic Computers" (hereafter abbreviated "advancement project") was announced--the part related to the installation of computers on 10 March, and the part related to development of software on 31 March. This article describes the outline of the advancement project; the process of deliberation developed at the three subcommittee meetings organized within the council will be covered in the next issue.

On this occasion, we would like to express our deep gratitude toward the secretariat and members of the Japan Electronic Industry Development Association for their cooperation as the working group in the hardware section of the council.

1. Purpose of Establishment of Advancement Project

Article 3 of the Act for the Promotion of Information Technology states that the advancement project is to be established from the standpoint of the promotion of information processing activities in Japan.

This act is the result of partial amendment of the Act for the Information-Technology Promotion Agency of Japan (IPA Act) in 1985. The details of the amendment consist of the addition of guidelines for the linkage of computers (hereafter abbreviated as "linkage guidelines") and provisions related to the software production industrialization system (the so-called Sigma system).

The advancement project established in 1986 is positioned at the core of this act. Through presentation of the way hardware and software programs, which are the fundamental resources making possible advanced computer utilization, will develop over the next 5 years, the advancement project forms a common concept on the integrated image of information processing in Japan and takes on the position of a line for the advancement of information processing.

MITI, it is reported, will also develop its policies for promoting information processing taking this advancement project into consideration.

2. Data Processing Promotion Council

The Data Processing Promotion Council (hereafter abbreviated "the council"), which announced the advancement project, was established in 1971 based on the provisions of the IPA Act. It is the sole council in the field of information processing in Japan, and its duty is to "investigate and deliberate important items for the promotion of information processing."

In the field of promoting information exchanges using computers, there is also the Information Industry Section of the Industry Structure Council in MITI. Since its establishment in 1967 for the purpose of constructing an integrated policy related to the promotion of information exchanges and information industries, this institution has been developing deliberations concerning the future development of the information industry (for hardware, software, information services, etc.). In other words, the Information Industry Section of the Industry Structure Council is where the policy applied to the suppliers of information processing facilities is deliberated.

As the council is required to exert leadership in forming a national consensus, it is composed of more than 30 members, including people of learning and experience, users of information processing facilities, and representatives of the information industry, as well as representatives of 14 related ministries and government agencies (permanent vice ministers).

Since its establishment, the council has deliberated on advancement projects each covering 5 years, as follows:

1st Advancement Project:	FY 1971 to 1975
2d Advancement Project:	FY 1976 to 1980
3d Advancement Project:	FY 1981 to 1985

3. The Fourth Advancement Project

Since 1970 the first to third advancement projects have presented concrete targets for the installation of computers and the development of software. By setting up target standards for the advancement of computer utilization, this effort has been playing an important role in the promotion of information exchanges using computers in Japan. In the extension of past advancement projects, the fourth advancement project for 5 years to 1990 has been established based on the current advancement and diversification of information processing placing more importance on the qualitative side.

According to the provisions in the Act for the Promotion of Information Technology, the ministers in charge of the industries have been allowed 4 years 1 day [as published] to establish and publish the linkage guideline in each industrial field under their control. As the linkage guidelines are to be determined "in consideration of" the advancement project, it was necessary to fix the new advancement project so the linkage guidelines can be determined from 4 years 1 day [as published] from the time the act came into force.

In the following, we will provide descriptions of the background ideas of the new advancement project and its characteristics separately for hardware and software.

(1) Major Points of Advancement Project Related to Hardware

1) Stressing the importance of users

The advancement project was established recognizing that the purpose is not information exchanges using computers themselves, but that the important thing is to improve the convenience and economy to users. To coordinate user requirements and reflect them in the advancement project, the Section for Promotion of Information Exchanges in Industries was established.

2) Introduction of qualitative targets

Unlike previous advancement projects, the new advancement project also determines qualitative targets for the advanced utilization of computers. (In the advancement project, this refers to seven items including "improvement of man-machine interface," "assurance of mutual application capability," "decentralized processing system," and "knowledge information processing system."

3) Increasing the number of beneficiaries and the arrangement of a foundation

The coming 5-year period is described as the expansion period for information exchanges using computers from the industrial field to other fields. To meet this trend, the foundation will be arranged by education on information exchanges using computers, etc.

4) Quantitative targets

The target of the actual working value of general-purpose digital computers at the end of FY 1990 is ¥13.2 trillion (Note: The actual working value refers to the total value of general-purpose digital computers in Japan calculated based on the computer delivery/trade-in investigation by MITI. The value includes the fees paid for rented computers in the purchase price category.). (The current figure is ¥6.69 trillion at the end of FY 1984.) This figure is estimated based on the estimated figures of GNP and ordinary profits. The average growth rate is around 12 percent and the backup market scale is estimated to be near ¥3 trillion in 1990. In the course of estimation, a sudden increase in computer demand was noticed since 1978 when on-line operations started to develop, indicating that the investment trend for computers has changed since that year.

The year 1978 was the first year for the shipment of domestically made personal computers. In addition, as seen in Figure 1 (Attendance at Data Show), it is also possible to interpolate that 1978 was the first year that words like "information processing" and "computer" acquired national recognition in Japan.

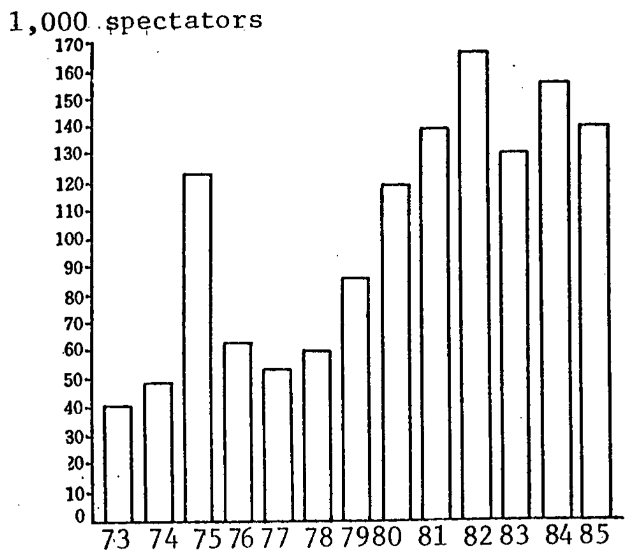

Figure 1. Attendance at Data Show

Note: In 1975 the show was held together with the Japan Computer Show

5) Examination of non-general-purpose computers such as personal computers

Personal computers, office computers, and minicomputers have not been examined in previous advancement projects. However, as these computers will have increased importance in the future, their positioning in the future development of information exchanges was also examined. It was discovered in the course of the investigation that the current computer classification method will no longer be suitable in the future because of the development of new hardware technology and the diversification of applications. As this causes problems in grasping actual conditions, it is recognized that it should be studied further, together with the problem of arrangement of statistics.

6) Introduction of viewpoint of internationalization

With the present internationalization of information-related industries, the Japanese information industry should try to achieve harmonious international development by establishing standards that match internationally accepted norms, etc.

(2) Hardware Advancement Project (unabridged version)

Advancement Project for Computer Utilization Related to Installation of Computers

The significance of information exchanges using computers is to contribute to the improvement of national life and the healthy development of the national economy through provision of faster and easier utilization of the information

required for various activities in the economic society and through the promotion of intelligent activities. In Japan the diffusion of computers has already attained the world's highest level, especially in industrial fields. Our task, which will be more important in the future, is to promote the advancement of their utilization, expanding the fields that can enjoy the convenience of information exchanges using computers and arranging a foundation that makes possible the advancement of information processing.

Future advances are expected to start with the utilization of computers among several enterprises and the development of new computer systems. It is important in these operations to make computer utilization more efficient and economical by reducing inefficiencies due to the lack of mutual operability between computers and the development of identical, and therefore redundant, software programs.

The fields of computer utilization will also be expanded from information processing departments to other departments within an enterprise, from big businesses to small businesses, from urban areas to rural areas, and from industrial use to use in the home and society. Especially computers with lower prices than general-purpose computers, such as personal computers, should be able to meet the expansion of user categories with improved, easier operability. They should be equipped to a greater extent with multiple functions and higher performance that make possible their use in new information-processing fields, and information-processing operations will also be further advanced by making use of such computers.

To respond to such future themes and to build a society based on information exchanges using computers at the same time satisfying the demand for the internationalization of Japan, we must supply computers and software programs that meet various needs while maintaining the mutual operability between computers by standardization. It is also necessary to ensure an increased number of information-processing engineers, which may be insufficient in the future, and to provide the foundation for information processing activities by providing basic knowledge on information exchanges using computers to the public through education and training, developing advanced high technologies, and by establishing data bases that simplify the accumulation and acquisition of information. These themes must be tackled by properly assigningparts of the job to everyone concerned in information processing, such as hardware manufacturers, the information-processing service industry, users, etc.

Based on the basic recognition above, this advancement project indicates the guidelines for the diffusion and advancement of information processing in Japan.

Targets in the Period Up to the End of FY 1990

(Qualitative targets)

1. Electronic computers with advanced man-machine interface facilities that can ensure easy and efficient operability to match the expansion of users without specialized knowledge of computers and the diversification and advancement of computer utilization.

2. Electronic computers with mutual applicability and adaptability to international standards that can be used in computer applications across several businesses and different industries which will be the key to the advancement of information exchanges using computers in the future economic world.

3. Dedicated high-performance electronic computers that can support the functions of an integrated decentralized processing system which performs various functions.

4. Electronic computers that can be used in a knowledge-information-processing system (artificial intelligence, etc.) which is equipped with pattern recognition functions and improves intelligent productivity in specific fields, supporting decisionmaking, etc.

5. Electronic computers used in image-processing systems which can process large amounts of pictorial, map, and pattern information at high speed, can handle this together with character code data, and is equipped with terminal equipment with easy input/output operations.

6. Electronic computers supporting data base systems which store, process, and provide information easily using relational data base technology, etc., in various systems and in various fields responding to the demand for the decentralization and personalization of information storage.

7. Electronic computers with high reliability and high security that respond to the expansion of applications of information processing and to the increased dependency of social activities on information processing.

(Quantitative targets)

8. (a) Based on the above considerations, the target of the active working value of general-purpose electronic computers at the end of FY 1990 is ¥13.2 trillion. In this definition, "general-purpose electronic computers" includes large, medium, small, and ultra-small computers.

(b) Among the above, the ratio of ultra-small computers is expected to increase in relative numbers.

(c) With respect to electronic computers that are not covered in the above targets, their target growth rate will be set at the same or slightly more than the growth rate of general-purpose digital electronic computer installations.

(d) Among computers grouped in (c), the target for the installation of so-called personal computers (including so-called workstations) is set higher than other types of computers.

(3) Major Points of Advancement Project Related to Software

The structure and basic concept for the present advancement project have been inherited from previous advancement projects. However, the present advancement project was established based on the following special considerations:

1) Importance of efficiency in program development

To meet the present insufficiency of software, both in quality and quantity, the improvement of efficiency in program development has been set as the first target.

2) Addition of knowledge-information-processing programs

The development of knowledge-information-processing programs is added as one of the targets because it is the future development direction of information processing and there is a strong need from users for expert systems, etc.

3) Addition of education programs

As one field of application programs, the development of education programs is added to meet the development of information processing in the educational field and the increased demand for information processing engineers.

4) Respond to the increasing importance of personal computers

The development of programs for personal computers is added to meet the increasing use of personal computers and the demand for dedicated software for them.

(4) Software Advancement Project (unabridged version)

Advancement Project for Computer Utilization Related to Development of Software

The diffusion of electronic computers in Japan has already attained the world's highest level, especially in industrial fields. It is estimated that the use of computers will further expand in various economic and social activities.

In recent years the importance of software in the introduction and operation of electronic computers has been rapidly increasing, and the trend is expected to continue in the future. Considering the increasing number of electronic computer installations, the efficiency and stable supply of software has become a very important theme for the smooth development of information exchanges using computers.

While hardware technology is progressing smoothly, software is also expected to advance in a direction that will make it possible to link progress in hardware to the convenience of users. It has become an especially urgent subject to utilize electronic computers across several businesses and to develop the organic integration of different systems. Also, as information exchanges using computers have expanded widely in important fields of society and among a wide range of users, it is a strong requirement to improve the reliability and operability of electronic computers. To solve these important problems for the development of information exchanges using computers, it is necessary to develop software programs based on an integrated policy in consideration of international harmony.

The goal of the present advancement project is to contribute to the improvement of national life and the healthy development of the national economy by indicating guidelines for the diffusion and advancement of information processing in Japan by determining the targets of the most widely used programs whose development is to be further promoted.

The targets for the period up to FY 1990 are set as follows. However, when an item is related to several of the classifications below, its development target will conform to these fields.

1. Control Programs

(1) Control Programs for General-Purpose Computer Systems

To meet the growth in scale of computer systems, in the performance of personal computers, and in the number of users, the expandability, reliability, and performance will be advanced at the same time while improving operability and applicability.

(2) Control Programs for Dedicated Computer Systems

To advance the utilization of dedicated computer systems used for specific purposes such as parallel processing, data base management, and knowledge-information processing, the basic performance will be arranged to match the specialized architectures at the same time while improving performance and reliability.

2. Communication Control Programs

(1) Computer Network Communication Control Programs

For the integrated utilization of network resources such as computers, terminals, and communications lines, protocols conforming to international standards will be used, processing efficiency, performance, and reliability will be improved, and protocol-conversion will be advanced for connecting computer networks with different network architectures.

(2) Computer Network Operation Management Programs

The efficient operation management of networks has become more important following the extension of the scope of computer networks into other industries. Therefore, the optimum control and remote maintenance functions will be improved and automatic network operation and fault-finding functions will also be improved.

(3) Data-Switching Network Communication Control Programs

To promote the advanced utilization of data-switching networks, the switching functions will be improved, additional functions and network management functions will be increased, the mutual connection facility between data-switching networks will be improved, and also the security function will be improved.

(4) Advanced Communication Control Programs

With various information styles such as characters, voice, images, and patterns and with various communication styles such as local area networks and personal computer communications, the efficiency of communications, including message exchange, will be advanced by arranging protocols systematically, improving conversion facilities between different information styles, improving flexibility with respect to various terminals, improving security functions, etc.

3. Language Processors

(1) General-Purpose Language Processors

To promote the advanced utilization of program languages, Japanese-language processing functions and data-base operation functions and portability will be improved at the same time while promoting the development of language processors conforming to the trends of international standards.

(2) End-User Language Processor

To make the utilization of electronic computers by end users easy, user-interfacing functions will be improved by simplifying entry operations, advancing Japanese-language processing functions, etc.

(3) System Description Language Processor

For efficient system software development, the level of system description languages and processing efficiency will be improved.

(4) General-Purpose Language Processors for Knowledge-Information Processing

For easier knowledge-information processing, processing efficiency and Japanese-language processing functions will be improved at the same time while enhancing the data-base operation functions and linkage functions with other languages.

(5) Decentralized Processing Language Processors

For easier decentralized processing, the functions and performance of description languages will be improved, andthe processing efficiency will also be improved.

(6) Problem-Oriented Language Processors

For easier creation of programs for specific fields, operability will be improved by enhancing conversational-mode functions, processing efficiency and image processing functions will be improved,and the application fields will be expanded.

4. System Development and Operation Support Programs

(1) System Development/Management Support Programs

For efficient, integrated management of system development processes, software history, etc., the source code, documents, and system configuration information will be managed by centralized control, the process, personnel, and capital expenditure will be planned and managed efficiently, manhours and quality control data collection and analysis functions will be improved, and user interfaces will be made more flexible.

(2) System Design Support Programs

For efficient designing of system configurations, including hardware, software, and data bases, the diagnosis performance and decentralized system design performance will be improved at the same time while making possible consultation functions using knowledge bases.

(3) Software Creation Support Programs

For the efficient creation of software, the program generator function will be improved and the parts-recycle support function will be made available.

(4) System Inspection/Evaluation Support Programs

For efficient testing of single or linked programs and for optimum inspection and evaluation of overall systems, the test data and environment generation functions will be improved, the quantitative measurement functions at the completion of inspections will be improved, and the performance estimation function will be enhanced at the same time while making possible an integrated system performance evaluation function.

(5) Software Maintenance Support Program

For efficient maintenance of finished software, the software modification and history management functions, program analysis functions, and program conversion functions will all be improved.

(6) System Operation Support Programs

For efficient system operation, flexibility will be improved according to various operation styles, and the management function of operation configuration according to load will be improved.

(7) Integrated System Development Support Program

For integral support of all system development processes, the data bases for integrated management of system information will be made possible, and system development and management programs will be increased in number and integrated.

5. Data Base Programs

(1) Data Base Management System Programs

Data bases, which store complicated and large amounts of data systematically, are becoming massive, decentralized, and diversified. To manage these data bases efficiently, large-scale data bases will have improved functions and performance, relational data bases will have improved performance, and decentralized data base management, such as data dictionary management, and multimedia data base management will be made possible. At the same time, user interfaces will be further simplified and the system reliability and security functions will be improved.

(2) Data Base Operation Support Programs

For efficient operation of the data base management system, the data base generation, reorganization, and fault recovery functions will be improved, data base design, evaluation, and maintenance will be simplified, and the data base conversion function will be improved.

(3) Information Retrieval Programs

For easier information retrieval, multimedia retrieval will be made possible, the retrieval functions will be improved using knowledge-information-processing technology, and the guidance function will also be improved.

6. Application Programs

(1) Fundamental Common Information Processing Programs

The utilization of electronic computers will be facilitated and advanced by improving user environment support functions, improving voice recognition functions, improving computer graphics functions, providing knowledge information processing functions, improving security functions, and improving robot functions.

(2) Educational and Training Programs

To serve the advancement of school education and training and improvement of education opportunities, the school education programs will be enhanced as will the social and industrial education programs.

(3) Social/Public Programs

To serve the improvement of the standard of national life, the functions and performance of service programs for individuals or households, as well as service programs for the general public, will be improved.

(4) Industrial Programs

To serve the advancement of businesses in various industrial fields, the functions and performance of business planning/management programs, design/production programs, and distribution/servicing programs will be improved.

(5) R&D Programs

For efficient and integrated R&D in the steps from planning, implementation, and evaluation of development projects and for the promotion of R&D in high-technology fields, the functions and performance of R&D support programs, such as the experiment support/analysis programs and simulation programs, will be improved. At the same time, the functions, performance, and operability of individual R&D programs will also be improved.

4. Conclusion

The outline of the advancement project is as shown above. In the next issue, we will report on the process of deliberations (including the report on the method of estimating value targets of computer installations) in the Hardware, Software, and Promotion of Information Exchanges Using Computers in Industries Sections established within the Data Processing Promotion Council.

20157/9365
CSO: 4306/5519

MG, GD TO BRIEF ASDF AGAIN ON FS-X PROPOSALS

Additional Presentations Proposed

Tokyo AEROSPACE JAPAN-WEEKLY in English 2 Mar 87 pp 5-6

[Text]

McDonnell Douglas (MD) and General Dynamics (GD) plan to brief again the Air Self-Defense Force (ASDF) on their respective proposals for the FS-X next support fighter. The two companies are expected to make additional presentations in late March.

For the FS-X selection, ASDF has so far made inquiries about the three candidates, including GD's F-16, MD's F/A-18 and Panavia's Tornado, and received answers from each of the three companies. To confirm some of the data, ASDF again made inquiries to the manufacturers. In addition, it sent a survey team to the three companies.

In the circumstances, both MD and GD proposed supplemental briefings on their FS-X proposals. The last briefings were made by the two companies in October 1986.

During the last briefings, however, they did not necessarily satisfy ASDF on their requirements. The briefings were inadequate, officials of the two companies admit. To supplement the last briefings, MD and GD proposed additional presentations.

MSDF To Receive First U-36A in March

Tokyo AEROSPACE JAPAN-WEEKLY in English 2 Mar 87 p 6

[Text]

The first Gates Learjet U-36A high-speed training support aircraft, which is being modified from the Learjet

36A by Shin Meiwa Industry Co., Ltd. (SMIC), will be completed in early March. It will be delivered to the Maritime Self-Defense Force (MSDF) on March 19.

The U-36A modified from the Learjet 36A is equipped with a missile seeker simulator in addition to a radar, avionics, firing training assessment devices, an ejector-pylon, a special communications system, a target towing system and a jammer system.

MSDF will use the U-36A for ship-to-air missile firing training and fleet air defense training against ship-to-ship and air-to-ship missiles

MSDF plans to deploy five U-36As under the current FY 1986-90 Medium-Term Defense Buildup Program (MDBP) and another aircraft under the next MDBP. It plans to form two units, each provided with three aircraft. The second U-36A is now already under modification work at SMIC's Tokushima Plant.

TRDI Head Visiting UK

Tokyo AEROSPACE JAPAN-WEEKLY in English 2 Mar 87 p 6

[Text]

Technical R&D Institute (TRDI) Director General Toru Yamashita is visiting the U.K. from February 21 until March 4 at the invitation of the British Government.

During this trip, Yamashita will visit the Ministry of Foreign Affairs, the Ministry of Defense, the Royal Ordnance Factories, Rolls-Royce, Marconi Defense Systems, and Ferranti Defense Systems and so on.

ASDF To Receive Last F-1

Tokyo AEROSPACE JAPAN-WEEKLY in English 2 Mar 87 pp 6, 7

[Text]

Mitsubishi Heavy Industries, Ltd. (MHI) will deliver the last F-1 support fighter to the Air Self-Defense Force (ASDF) on March 9. To commemorate the last delivery, MHI will hold a ceremony at Nagoya Aircraft Works' Komaki-Minami Plant.

The F-1 is a modification of the T-2 advanced jet trainer. The first production contract for 18 aircraft was

awarded in FY 1975. Since the first F-1 was delivered in FY 1977, MHI has received orders for 77 aircraft and delivered them over the past ten years.

The last or the 10th contract for three aircraft was placed at about ¥4.8 billion for the airframe and ¥2.2 billion for the six engines under the FY 1984 budget.

Of the last three aircraft, MHI delivered one each in December last year and January this year. The last or the No.77 aircraft will be delivered on March 9.

/9274
CSO: 4307/015

PANAVIA PROPOSES 'TORNADO-J' FOR FS-X

Military Technology Exchanges Proposed

Tokyo AEROSPACE JAPAN-WEEKLY in English 23 Feb 87 pp 1, 2

[Text]

Panavia Aircraft announced at a press conference on February 12 in London that the company proposed a plan to develop a new version of its Tornado fighter aircraft jointly with Japan for the FS-X next support fighter of the Air Self-Defense Force (ASDF).

The proposed new aircraft called a "J" version is modeled on the Tornado ADV aircraft which is currently manufactured for the British Royal Air Force (RAF). The proposal is aimed at developing jointly with Japan a new fighter which will satisfy all requirements of ASDF. For this purpose, Panavia has also proposed that an agreement on military technology exchanges should be concluded between Japan and Europe.

The FS-X options are now narrowed down to purchase of off-the-shelf foreign aircraft (including Panavia Tornado, General Dynamics F-16 and McDonnell Douglas F/A-18) and development of new aircraft (either domestic development or joint development with foreign manufacturers).

The joint development proposals of the U.S. have recently been in the spot light. In the circumstances, Panavia's joint development proposal is aimed at countering the U.S. manufacturers.

Under the FS-X operational scenario, ASDF plans to deploy new support fighters at Matsushima Air Base in Miyagi Prefecture for attack operation against enemy fleets approaching Hokkaido or the coast of Japan Sea.

In time of emergency, however, the FS-X fighters may be deployed down south at Hyakuri Air Base because even Matsushima Air Base is too close to the front line.

The FS-X will have to fly up to the east coast of Hokkaido to attack enemy ships and return to the base. In some cases, the fighters will have to perform air-to-air combat during their missions.

According to ASDF's requirements, the FS-X has to be armed with four air-to-ship missiles (or six 500-pound guided bombs), two air-to-air missiles and a 20mm machinegun (with 500 rounds). The Panavia Tornado and the McDonnell Douglas F-15E dual-role fighter are the only aircraft now available to satisfy such requirements and an operational scenario.

This is why Panavia has proposed a joint development of the Tornado-J. Although no details of the Tornado-J proposal have been disclosed yet, Panavia is now attracting much attention of the Japanese aircraft industry as well as ASDF's engineering staff who have been concerned about a joint development with the U.S. only.

Europe believes that the FS-X is a good chance for Japan to appeal its efforts of correcting the current trade imbalance between Japan and Europe. If necessary, West Germany, the U.K. and Italy will ask Prime Minister Yasuhiro Nakasone for Japan's introduction of the Tornado at the coming Venice Economic Summit meeting in June.

Low-Temperature Tests on XT-4

Tokyo AEROSPACE JAPAN-WEEKLY in English 23 Feb 87 p 3

[Text]

The Air Self-Defense Force's Air Proving Wing (APW) conducted low-temperature tests of the XT-4 medium jet trainer from January 27 until February 9 at Chitose Air Base in Hokkaido.

Using the No.4 prototype aircraft, APW made various tests such as starting the engine in a low-temperature environment and tests on various systems both at takeoff/landing and in flight. The tests were successful, according to ASDF officials. In March this year, APW plans to perform takeoff and landing tests in cross wind conditions, using the No.2 prototype.

Since the No.4 prototype fitted with spin-test gear was delivered in July last year, ASDF has been conducting tests on four prototypes in parallel.

In a basic arrangement, the No.1 prototype is used for on flutter and engine functions tests, the No.2 prototype for flight characteristics and flight load tests, the No.3 prototype for system functions and mission compatibility tests, and the No.4 prototype for spin tests.

But APW is not necessarily following this arrangement and using them for other tests, if necessary. The low-temperature test on the No.4 prototype is one of such examples. The No.4 prototype will continue spin tests when it returns to Gifu Air Base.

TRDI Returns T-2 CCV To ASDF

Tokyo AEROSPACE JAPAN-WEEKLY in English 23 Feb 87 pp 3, 4

[Text]

The Technical R&D Institute (TRDI) returned on February 2 the T-2 CCV (control-configured vehicle) research aircraft to the Air Self-Defense Force's Air Proving Wing.

The CCV research aircraft was modified from the Mitsubishi T-2 advanced jet trainer. It was equipped with maneuvering flaps, vertical and horizontal canards and the fly-by-wire system to realize the CCV capabilities.

The aircraft underwent various tests in FY 1984-85. Since it all tests were completed, TRDI took out all CCV equipment from the aircraft and returned it to ASDF.

/9274
CSO: 4307/016

SAFETY OF DOMESTIC NUCLEAR POWER PLANTS DISCUSSED

Tokyo PUROMETEUSU in Japanese Jul 86 pp 17-20

[Article by Atsuyoshi Morishima, special researcher for the Japan Atomic Energy Research Institute]

[Text] Containment of Ash as the Basis of Safety

The nuclear power stations of Japan presently have 32 units of nuclear reactors operating with a total capacity of around 24.5 million kw. Since 31 units of these are of what we call the light water type, the author will only deal with the safety of this type of reactor.

Nuclear power generation, as opposed to conventional fire power generation, builds up substances of high radioactivity in the ash produced by the consumption of nuclear fuel. The quantity of the accumulating ash is dependent exclusively on the output and the period of operation of the reactor and is independent of the type of reactor. The radioactivity of ash of long half-life increases as the fuel burns, whereas the radioactivity of ash of high radioactivity, which generally has a short half-life, stays constant after reaching a certain level since the decaying radioactivity and forming radioactivity become equal.

The quantity of radioactive ash building up, therefore, does not grow in proportion to the total ash that contains nonradioactive ashes.

The author seems to have made a rather lengthy description of radioactive ash which is inclusive of stable fission products and will be referred to as FP hereinafter. The problem of how to contain FP is the basis for ensuring the safety of nuclear reactors so that the public can be protected from the hazards of radioactivity in the event of reactor machinery failure of operating error. One may call a reactor extremely safe if the ash can be encased in strong multiple-layer vessels; in other words, the severest conditions conceivable. However, the term "severe" must not be taken literally lest it become unrealistic. It is also important to select a reactor type which, according to the law of nature, eases the degree of severity needed as much as possible and to design the reactor carefully and appropriately for this purpose.

How To Contain Radioactive Ash in the Event of Reactor Accidents

The light water type of nuclear reactor [hereinafter called the LWR] is favored over the other types in that the reactor follows natural law in which it ceases to operate with the loss of coolant.

Even in the event of an accident, the LWR can be terminated without exposing the public to radioactive hazards, provided the following conditions are successfully attained: 1) termination of nuclear reaction is verified; 2) cooling of the reactor core is ensured, and 3) FP is contained in the reactor.

The phenomena of accidents, though diverse and innumerable, may be represented by the loss of the coolant with regard to the containment of FP and in terms of severity. The loss of coolant means that at least one of the many strong vessels encasing the FP with several layers has failed and that the removal of the decay heat generated by the FP has become unsatisfactory, resulting in a rise in the temperature of the cladding, one of the FD vessels, and its failure to contain. The loss of coolant, at this juncture, leads to the spontaneous cessation of the nuclear reaction and one, therefore, may cool the core only for the purpose of removing the decay heat by actuating the emergency core-cooling system. (Injection of, for example, a boron solution raises the chances of stopping the nuclear reaction in the case of pressurized water reactors.

A safeguard circuit, in this connection, is installed through which various facilities--referred to as engineered safety features and includes the emergency core-cooling system and the containment vessel--display the detection of the loss of coolant and verify FP containment.

Major Requirements for Ensuring Safety

Where accidents of coolant loss are concerned, various emergency core-cooling systems are incorporated in the reactor, and operate regardless of whether the break of the primary coolant system involves pipings of large or small diameters and where the break is located, among other things. The relevant system for, e.g., standard pressurized reactors of today, is comprised of three parts--the accumulated pressure injection system, the high pressure injection system, and low pressure injection system. The safety protection system and the engineered safety features referred to above are extremely important in ensuring the safety of nuclear reactors and require the highest reliability possible. Consideration, therefore, is given to ensuring their functions and relevant machinery and systems are multiplied and diversified and sometimes rendered independent of each other.

In addition to the emergency core-cooling system described above, countermeasures to cope with other types of accidents are also incorporated.

Three steps of countermeasures are usually worked out for ensuring safety: first step, preventing accidents; second step, blocking the spread of accidents; and third step, limiting damages at the time of accidents.

The nuclear power stations in operation throughout the world total 351 units; 32 units of these at 14 sites are being operated in Japan. Though they are distant from urban communities and may not be felt closely associated with the life of the people, these nuclear power stations provide one-fourth of the electricity consumed.

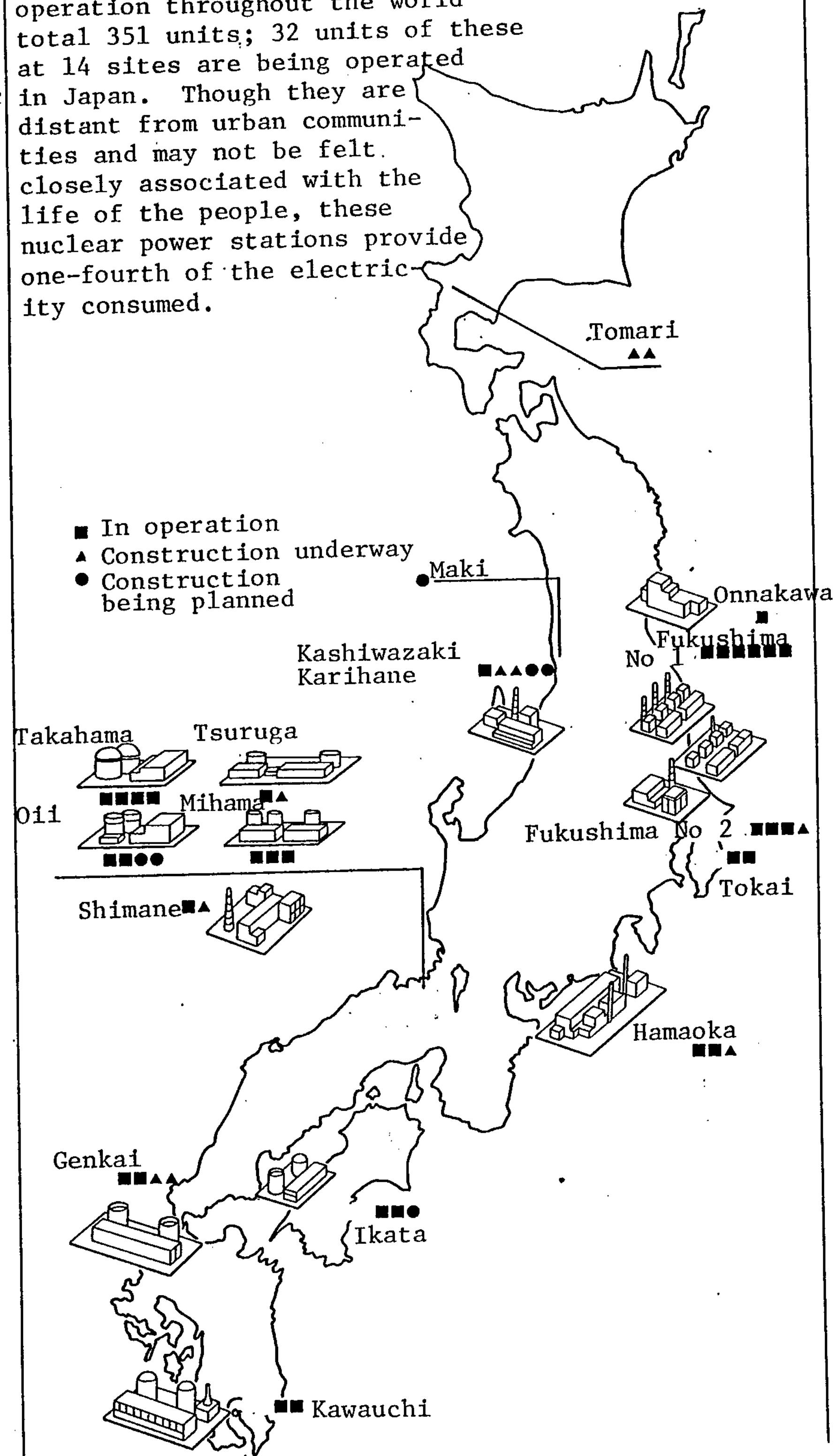

Figure [Location of Nuclear Power Stations in Japan]

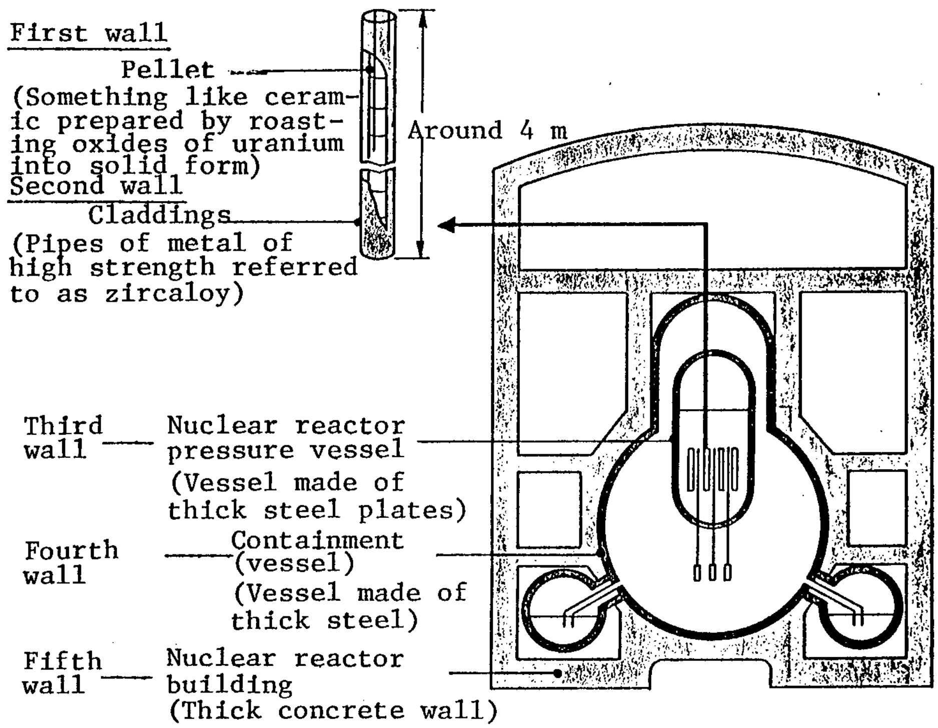

Figure [Nuclear Fuel Encasement]

The nuclear power station has most of the radioactive materials contained in the nuclear reactor with multiple protective walls surrounding the reactor:

The first wall is the nuclear fuel pellet, which is made by roasting oxides of uranium into a solid form at high temperatures and in which most of the radioactive material is contained. The second wall is the cladding in which radioactive substances that leaked from the pellet is contained. The third wall is the nuclear reactor pressure vessel which, together with the pipes connected to it, contains radioactive substances that somehow leaked from the cladding. The fourth wall, the containment (vessel), which is an airtight vessel made of steel, prevents radioactive substances from flooding out in rare accidents where the reactor fails. The fifth wall is the reactor building. This building, by means of multiple filters, etc., blocks the release of radioactive substances to the outdoors.

In nuclear power facilities other than a nuclear power station, in fuel reprocessing plants, for example, the radioactive substance is contained on the basis of the same concept.

The emergency core cooling system and the containment vessel represent the third step. Of most importance, however, is the first step, which must be attained by maintaining a high quality of and imparting high reliability to the systems and machinery of the reactor through prudent and meticulous designing, manufacture, and maintenance on the one hand and by providing sufficient education and training for the operating personnel on the other. The multiplexing and diversification of machines and instruments do not make sense unless they are of adequate reliability. It may not be an overestimation, in this connection, to say that the nation is presently at a high level with regard to both manpower and machinery.

20,128/9365
CSO: 4306/2632

ENERGY

BRIEFS

SOLAR CELL--Tokyo, Jan. 28 KYODO--The New Energy Development Organization (NEDO) announced Wednesday the successful development of a 1,200 square centimeter amorphous solar cell with the highest ever conversion efficiency ratio of 8.1 percent. The conversion efficiency ratio represents the rate at which a solar cell converts solar energy into electrical energy. NEDO said the high ratio was achieved by the inclusion of a buffer layer within the cell which reduces the amount of electrical power absorbed before it has a chance to leave the cell. [Text] [Tokyo KYODO in English 0905 GMT 28 Jan 87 OW]

/9716
CSO: 4307/014

BRIGHT FUTURE FOR NEW MATERIALS DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Dec 86

[Interview with Naomichi Suzuki, Director, MITI's Basic Industry Bureau, by Ko Watanabe, Editor, NIKKO MATERIALS, date and place not given]

[Text] The uncertainty of market conditions and an oversupply of raw materials continues worldwide. In the case of Japan, there is an added element of the "strong yen" so all segments of the materials industry are in a state of serious depression. Naomichi Suzuki, Director of the Basic Industries Bureau of MITI, acts as supreme commander of the ministry's industrial policy. He has stated that in terms of his basic thinking, the high priority issue is that "While worldwide demand for raw materials is expanding, Japan seeks to enter and expand the high added value and high performance materials sectors." Additionally, with respect to the problem of the strong yen, he has remarked, "The 1 dollar to 150 yen range is the peak and the yen will probably eventually decrease in value. The Government is exerting maximum efforts to promote domestic demand. At any rate, Japan cannot exist solely on the service industries and sophisticated financial management. The people who produce should be treated with greater care. And then the future for new materials markets will grow immensely."

Petrochemical Industries Are Relatively Prosperous

[Question] It is called "era of suffering by the resources-materials industries" and the basic industries, particularly the materials industries, are being hard hit worldwide, aren't they?

[Answer] In addition to the low growth in the economy we have a decrease in consumer unit spending, or, in other words, because the economy is thinner and narrower, demand is having difficulty growing. However, there is no change in the importance of materials and this sector of demand will continue to grow in the future. But, in this state of recession, the petrochemical industry is faring well, isn't it? With the high values of engineering plastic some West German petrochemical industries have had 30-50 percent growth rates in their high performance materials.

[Question] Japan also seems to be in relatively good condition with respect to its petrochemical industries, doesn't it? The reduction in base cost of

petroleum products has, of course, contributed and also the early switchover to the new materials sectors has been successful. However, iron and steel, nonferrous metals and the aluminum smelting industries are in awful shape.

[Answer] In addition to demand decrease and lower market prices, in the case of Japan, the sudden rapid rise in the yen can be blamed. Japan's iron and steel industry's performance is getting worse. However, they still have the world's best technology, facilities and human resources, so, if we are only able to ride out this period of high yen, everything will be all right.

Promoting Domestic Demand With Large-Scale Supplemental Budget

[Question] The high yen is the problem and there also appears to be strong criticism that the Government's responses are lukewarm.

[Answer] No! Our intention is to do our utmost. (Laughter). First, as a measure to deflate the high yen value, a large-scale supplemental budget of 3.6 trillion yen has been introduced in this special Diet session and every effort is being exerted to promote domestic demand.

[Question] What is the outlook for currency rates which even the Gods (Laughter) cannot predict?

[Answer] If one knew that he would be the richest man in the world. (Laughter). However, basically, the 150 yen to the dollar is clearly excessive. There appears to be a strong outlook that the rate will go to the 170 yen level by year end. At any rate, the economic superpower Japan cannot exist on only the service industries and sophisticated financial management alone. The production people who produce things should be treated with greater care.

Deindustrialization and the International Division of Labor

[Question] I agree absolutely, and that is why you are the Director of the Basic Industry Bureau (Laughter). However, despite this, imports of materials increase due to the high yen value and there is more activity in moving production facilities overseas. In other words, isn't there a concern for the hollowing out of industry?

[Answer] In the larger flow of things, international division of labor may be unavoidable. Japan should perhaps further advance the shift toward such new industries as microelectronics, new materials and biotechnology and, at the same time, solve the issue of deindustrialization.

[Question] Well, there seems to be some opinion that the current Industrial Structure Law (Temporary Measures Law Pertaining to Structural Reform of Designated Industries) ought to be restudied.

[Answer] We will continue structural reform until June 1988 when the law expires. Aside from this, we are studying such issues as the effect of the high yen on industry and the related issue of international division of labor

and the increase of manufactured goods and overseas investments, in order to cope with future policy. In this case the coal, metal mining and shipbuilding industries are intimately tied to regional economies and countermeasures are very important.

[Question] The closing of metal mines is continuing and aluminum smelting seems to be on the verge of collapse, doesn't it? How did the Japan-U.S. talks on aluminum go?

[Answer] We were asked to make tariff reductions ahead of time, but we firmly turned this down. The continuance of Japan's aluminum smelting industry is definitely difficult, but aluminum processed products are growing. I would like to see forward movement by solving the issue of excessive sales competition.

By the Year 2000 New Materials Will Rise to 5.4 Trillion Yen

[Question] What are the prospects for the new materials industry?

[Answer] This side of the picture is rose colored. (Laughter). According to research by the Industrial Structure Research Council the market scale for new materials in 1985 was 1.181 trillion yen. This is broken down into 275 billion yen for high performance high polymer materials, 36.0 billion yen for new materials, 40.0 billion yen for compound materials and 830 billion yen for fine ceramics. It is estimated that by the year 2000 this will be approximately 5.4 trillion yen. Ceramics will be 1.9 trillion yen, high polymers and new metals 1.5 trillion yen each, and compounds .4 trillion yen.

[Question] That is tremendous, isn't it? And, of course, there is also the applied products market in new materials---

[Answer] If all such sectors as large-scale integrated circuits, solar batteries and high performance separation films are included, it comes to 52.5 trillion yen--an increase of tenfold.

[Question] What is the outlook for the microelectronics sector?

[Answer] The new products market for such items as the JJ elements and gallium arsenide will be 31.9 trillion yen in the year 2000. The applied products market for such items as computers, office equipment and aircraft will be 131.3 trillion yen giving an estimated total of 163.2 trillion yen.

Full Efforts in the Development of the Biotechnology Sector

[Question] More and more courage wells up within me. (Laughter). And, MITI is very enthusiastic concerning biotechnology, isn't it? Of course, both the Agriculture, Forestry and Fisheries Ministry and the Health and Welfare Ministry are involved in this issue.

[Answer] There is no question but that biotechnology will become one of the important pillars of the next generation. MITI has, from quite some time ago, started research and development of biotechnology. For example, they established a research association based on the R&D System for Next Generation Industries and have been engaged in technology for utilization of recombinant DNA, bioreactors and bio elements as well as fuel alcohol technology developed based on bacteria.

[Question] What are the plans for 1987?

[Answer] In the sector of applied biological performance technology, there is the large-scale joint international research on the "Human Frontier Science Program." This is a program to develop new substances and innovation of production processes which imitate the chemical processes of living bodies. It also embraces the development of new data processing and controls and electronic technologies which imitate the functions and structure of the brain and nervous systems. We are looking forward to their outcome.

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CSO: 4306/7044

RECENT DEVELOPMENTS IN METALS, PLASTICS, CERAMICS DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Nov 86 pp 24-30

[Excerpts] Metals

IC Pin of Copper Alloy--Thermal Conductivity Is More Than 10 Times That of Conventional Products

Kobe Steel, Ltd., has developed a copper alloy, "KPGA-2" (brand name) for lead pins used in PGA (pin grid array) which is a high-density mounting IC (integrated circuit).

Up to now, a 42-alloy containing 42 percent nickel has been used in lead pins for PGA, but it was necessary to enhance the electrical conductivity with a view to raising the thermal dissipativity and to increasing the operating speed. Also, copper alloys are superior to the 42-alloy in thermal dissipativity and electrical conductivity, but a C194 (consisting of copper, iron, and phosphorus) which has been used conventionally has a problem in that its strength is extremely low.

The copper of the new product contains a very small amount of nickel, cobalt, silicon, and zinc. It is manufactured by using a method whereby after an element wire is heat-treated for 5 minutes at a temperature of 850 degrees centigrade, it will be cooled at a speed of a temperature of 14 degrees centigrade per minute and will be further heat-treated for 15 minutes at a temperature of 500 degrees centigrade. As a result, the tensile strength is 53.6 kilograms per millimeter, which is equivalent to that of the 42-alloy, and the Vickers hardness if 158, which is higher than 142 of the 42-alloy. Assuming that the electrical conductivity of pure copper is 100, that of the new product is 46.1, which is much higher than 2.7 of the 42-alloy. Also, the thermal conductivity if 0.52 calorie per centimeter per second, which is more than 10 times 0.04 calorie per centimeter per second of the 42-alloy.

The new product is manufactured by processing a pin with a diameter of 0.46 to 3 millimeters and a length of 4 to 6 millimeters and by soldering silver. The company will put such new products on the market.

(2) 99.95 Percent Ultra-High Purity Iron Powder

Toho Zinc Co., Ltd., was making high-purity iron oxide powder on an experimental basis in Fujioka Refinery (located in Gunma Prefecture), of the company, and has currently succeeded in making more than 99.95 percent ultra-high purity iron oxide powder. The company will construct a facility with a monthly production capacity of 5 tons and will start operating the facility within the year. It is said that this is the first time that a product with the purity which is more than 99.9 percent has been developed.

The ferric chloride and green vitriol are generated by pickling steel plates. Conventional high-purity iron oxide has been manufactured by using ferric chloride and green vitriol as raw materials, but the purity was 99.3 to 99.8 percent at most.

For this reason, the company has succeeded in developing a new product with a purity of more than 99.95 percent by using a method whereby after 99.9 percent high-purity electrolytic iron as a raw material is dissolved, it will be sintered so that it can have a crystal structure from which impurities can be removed readily.

The chlorine, sulfate ion, sodium, silicon dioxide, etc., cause the reduction in reproducing functions of the magnetic head. A minimum amount of these elements is contained in the new product. For this reason, it can be expected that the demand for new products will increase in the field of equipment such as VTRs (video tape recorder), computers, etc., in which high-class magnetic head materials are used. In addition, the new product will probably be used as a functional material for electronic parts such as varistor based on iron, thermo-sensitive device, etc.

(3) Development of Vertical Magnetizing Method FD

Toyobo Co., Ltd., has succeeded in developing an FD (floppy disk) having a vertically magnetized film, and has started shipping its samples. The storage capacity is available in two kinds, i.e., 4 megabytes and 6.4 megabytes. The material of recording films is a barium ferrite.

The company has taken great interest in the FD Department as a part of the plan for branching out into a new business field, and put a coating type FD with a size of 3.5 inches and a storage capacity of 1 megabyte on the market in this spring.

The new product employs a vertical magnetizing method whereby magnetic materials are arranged vertically to the base film. Compared with conventional FD's employing a lateral method, the new product has an extremely large number of magnetic properties per unit area.

The vertical magnetizing method is available in two kinds, i.e., coating method and sputtering method of deposition for forming magnetic layers. It is possible to manufacture vertical magnetizing films made of barium

fertite by using the coating method, and to manufacture those made of cobalt nickel or cobalt chrome by using the sputtering method. The reason why Toyobo Co., Ltd., has branched out into the FD field is that the company has made a speciality of the field of polyester used in base films and has commercialized the adhesive resin used for uniformly dispersing magnetic materials on base films.

(4) Metallic Rhenium Powder is Domestically Produced for the First Time in Japan.

Sumitomo Metal Mining Co., Ltd., was constructing a facility for recovering metallic rhenium, and was conducting trial operations of the facility in its Toyo Smelter of Besshi Division located in Ehime Prefecture. The company has currently succeeded in these trial operations, and has started operating the facility on a commercial basis. Metallic rhenium powder is required in a catalyst used to manufacture alloy and lead-free gasoline for heaters, and is produced for the first time in Japan. The company is scheduled to produce the metallic rhenium powder at a rate of 1,200 kilograms per year.

Rhenium evaporated from a smelting furnace in the copper refining process is absorbed and recovered with a special ion exchange resin. As a result, metallic rhenium is obtained. The purity is more than 99.99 percent, which surpasses 99.9 percent of imports. The diameter of particles is within 1.5 to 5.0 micrometers, and can be adjusted freely.

Also when necessary, the company will put ammonium per-rhenium acid as well as rhenium powder on the market.

Rhenium is added to tungsten, molybdenum, rhenium catalyst, or platinum used for manufacturing high-octane gasoline. Such rhenium is used in the electron tube heater, X-ray target material, etc. The price is ¥ 400 to 500 per gram, being high.

(5) Vibration-Proof Aluminum Alloy Can be Readily Processed Even in the Complex Shape.

Sumitomo Light Metal Industries, Ltd., has developed a vibration-proof aluminum alloy, "XW24" which can be readily processed even in the complex shape by using super-plastic phenomena, and has started shipping its samples.

Most of the vibration-proof materials which have presently been put to practical use are based on ferrite, and are composite materials based on alloy, such as treating type materials. These vibration-proof materials have the disadvantages of being expensive, the cost of heat-treating them is high, and it is difficult to finely process them. The market scale of these vibration-proof materials is about 400 tons as of 1985.

The vibration-proof aluminum alloy can be processed in the complex and fine shape at a processing temperature equivalent to about half of the melting point of this new product, because the new product shows super-plastic

phenomena at the processing temperature. Also, the internal friction is large, because the new product has the fine metallographic structure and composite eutectoid structure. Therefore, it is said that the new product converts vibration energy into thermal energy with the internal friction of the metallographic structure and exercises its high-vibration-proof capacity. For example, the logarithmic decrement of the vibration energy with a vibration number of 20 hertz is 0.032, which is three times that of usual aluminum alloy.

For this reason, it can be expected that the demand for new products will increase in various fields such as cover of gauges, chassis of precision processing instruments, shell plate panel of automobiles, sound-proof panel, etc.

(6) Success of Development of Spherical and Polyhedral Precious Metal Fine Powder

Tanaka Kikinzoku Kogyo K.K. has succeeded in developing fine powder made by mixing powder of copper and that of spherical and polyhedral precious metals such as platina, gold, silver, etc., used for thick film paste and brazing filler materials, and has started shipping its samples.

The only unshaped powder called, "Black" with a diameter which is larger than submicron can be manufactured effectively by using conventional methods, or the only powder with a diameter which is more than tens of micrometers can be manufactured effectively by using an atomizing method, etc.

Over against this, the technology developed by the company possesses the following features: 1) the new product is a spherical or polyhedral particle, 2) it is possible to control the diameter of particles within the range of 0.5 to 10 micrometers because the diameter is small, 3) the particle size distribution is sharp, 4) the pure level is high, 5) the amount of alkali metal, etc., contained in the new product is small.

Thanks to these features, it has become possible to use the new product in the catalyst, brazing filler material, thick film paste for platina, gold, silver, etc. It is anticipated that the demand for the new product as a functional precious metal powder will increase from now on.

Also, the company has succeeded in fine-powderizing palladium, and is developing the fine powderization of ruthenium, rhodium, iridium, nickel, cobalt, etc.

The company has applied for 18 patents for the above new technology.

Plastics

Liquid Crystal Display Alternative Material Formation of Outlook of Development of PITN

Showa Denko K.K. has projected a plan for the development of the PITN (polyisothianaphthene) which is a new electro-conductive polymer material. Of the existing electro-conductive polymer materials, this material has an energy gap value which is closest to that of metal, is excellent in transparency and heat resistance, and can withstand a temperature of 300 degrees centigrade.

Usually, the PITN is manufactured by polymerizing a monomer isothianaphthene. The company has currently succeeded in developing the technology for synthesizing PITN in the optional shape. The PITN was changed to a thin film by using an electrolytic polymerizing method or was powderized by using a chemical polymerizing method in order to develop this technology.

The PITN possesses the following features: 1) compared with existing electroconductive polymers such as polythiophene and polyacetylene, the PITN is the closest to metal and is excellent in transparency and heat resistance, because the energy difference between low electron band and electro-conductive band is 1.0 eV, while that of the polythiophene is 2.0 eV and that of the polyactylene is 1.4 eV, 2) the PITN has a clear electrochromism (light blue and light green), 3) the PITN is electrochemically stable.

Therefore, it is expected that the PITN will be used as a new displaying material which can correct defects of the liquid crystal display.

Ceramics

Quartz Oscillating Type Moisture Meter Which Can Continuously Measure a Very Small Amount of Water Contained in Gas

Shimadzu Seisakusho Ltd. has developed two kinds of quartz oscillating type moisture meters, "MAH-2 Type" and "MAH-50 Type" which can continuously measure a very small amount of water contained in high-purity gas used in semiconductor manufacturing lines, etc., and has started putting them on the market.

A very small amount of water, etc., which has a bad influence on the device manufacturing process, is contained in high-purity gases such as nitrogen, hydrogen, argon, etc., used in the semiconductor manufacturing process. In recent years, the industrial world has needed a moisture meter which is high in stability and reliability and which can measure a smaller amount of water with high sensitivity, because semiconductor devices have been highly integrated.

The above new moisture meters possess the following features: 1) it is possible for them to continuously measure a low concentration water with high accuracy, because they are equipped with a moisture sensor which can detect a very small amount of water, 0.1 parts per million, 2) the gas modulation method was adopted as a measuring method, 3) they have little drift and are excellent in stability, because their sensors are incorporated in their baths whose temperatures are precisely controlled, 4) the sensitivity can be

readily calibrated with a moisture generator incorporated in them. 5) the response time is extremely short, being within 5 minutes, 6) water can be discharged promptly from the measuring inside, and the measurement work can be started after a short waiting time, because they are equipped with an automatic circuit which forcibly heats a water measuring section as soon as their operations are started.

Ceramic Reinforced Aluminum is Developed.

Showa Aluminum K.K. has succeeded in developing a ceramic reinforced aluminum excellent in high temperature strength. This new product is suitable for automobile engine parts, etc., which need light weight and heat resistance. It is an isotropic and composite material in which fine ceramic particles are uniformly dispersed in aluminum alloy powder by using an MA (mechanical alloying) method.

The method of manufacturing the new product is as follows: after the aluminum alloy powder and fine ceramic particles with a particle size of less than 1 micrometer are alloyed mechanically in an inactive gas atmosphere, the compound will be dispersed uniformly in the aluminum alloy of the matrix (base material); it will be alloyed mechanically, and will be molded in order to make an ingot. This ingot will be worked plastically, i.e., extruded or forged with a view to variously forming the ingot.

The drape and wettability (adhesion) between matrix (aluminum alloy) and reinforced material (ceramic) have been enhanced by uniformly dispersing fine ceramic particles in the aluminum alloy. Therefore, the ceramic reinforced aluminum has become an isotropic and composite material excellent in strength, rigidity, hardness, heat resistance, wear resistance, etc. The price is high, being ¥20,000 to 30,000 per kilogram, but it is anticipated that the mass production of new products will lower the price considerably in the future.

Silicon Carbide Lightweight Wafer Board Conforms to High Integration and Large Caliber.

Toshiba Ceramics Co., Ltd. has developed a silicon carbide light-weight wafer boat, "TPSS Boat-E (branc name)".

The wafer boat is used in the heat treatment processes such as diffusion, oxidization, etc., in manufacturing of semiconductor IC devices. Up to now, wafer boats made of quartz glass have mainly been used in the above processes. In recent years however, the industrial world has eagerly required a new wafer boat which is lightweight, highly pure, is not deformed with heat, and is excellent in dimensional accuracy and washability, because wafers with the larger caliber have been used and devices have been highly integrated in semiconductors.

The company has succeeded in obtaining the new wafer boat with a weight which is half that of conventional wafer boats without any decrease in practical strength by using the following items: 1) a homogeneous and high strength material was used in the new wafer boat, 2) the new wafer boat is thin, because of the use of a special molding method, 3) the contamination of the new wafer boat and the deterioration of the strength of the new wafer boat were restrained by improving the shape of conventional wafer boats. As a result, the new wafer boat, "TPSS Boat-E" possesses the following features: 1) it is easy to control diffusion furnaces, because the heat capacity of new wafer boats is small, 2) the yield and quality are enhanced, because wafers are uniformly heated or cooled, 3) the contamination amount is reduced by half, 4) the life of new wafer boats is long, because the degree of damage caused by thermal deformation or spalling and that of fatigue fracture caused by repeated thermal stress are lowered.

Fine Ceramic Speaker Diaphragm Is Coated with Diamond.

Victor Company of Japan Ltd., and Sumitomo Electric Industries, Ltd., have jointly developed a speaker diaphragm, "Pure Diamond Ceramic Diaphragm" in which pure fine ceramics are coated with a crystalline diamond thin film.

In recent years, audio sets have been digitized to a remarkable extent. In compliance with this tendency, Victor Company of Japan, Ltd., is developing a high performance speaker, and completed an alumina polycrystalline burning product only for fine ceramics, "Pure Fine Ceramic Diaphragm" for the first time in the world.

The contents of the above crystalline diamond thin film coating technology are as follows: a crystalline diamond thin film with a thickness of 2 micrometers is formed on the surface of the pure fine ceramics by using a plasma CVD (chemical vapor deposition) method. It is difficult to coat the surface of conventional metal foil diaphragms made of aluminum, titanium, or the like, because the reaction temperature at the above formation is high, being more than 700 degrees centigrade. It is possible to coat the surface of only pure fine ceramic diaphragms with the high heat resistance.

This crystalline diamond thin film itself has physical property values equivalent to those of natural diamonds. For example, the propagantion velocity, Young's modulus, and density are 11,000 meters per second, 4.6 x 10", and 3.8 grams per cubic centimeter, respectively, while those of conventional pure ceramic diaphragms are 9,400 meters per second, 3.4 x 10", and 3.8 grams per cubic centimeter, respectively. As a result, the dynamic range (more than 90 decibels) and the sound play reproduction can be improved, and the quality of sound can be enhanced.

Electromagnetic Wave Shielding Glass for Construction Work Has an Effect of More Than 40 Decibels in Medium Wave Bands.

Nippon Steel Glass Co., Ltd., has developed an electromagnetic wave shielding glass for construction work, and has tentatively delivered it in a broadcasting studio of a radio station. The electric field shielding effect is more than 40 decibels in a region or 0.3 to 1,000 megahertz, and the visible rays transmission factor is more than 50 percent.

This electromagnetic wave shielding glass is manufactured by putting an electro-conductive metallic plating polyester mesh in a space between two colorless and transparent intermediate films. The new product is constructed so that electrolytic copper foils of terminals are contacted with the mesh at the inside of one side of the glass and are drawn out to the outside of the other side of the glass.

The company has tentatively delivered this electro-magnetic shielding glass in a newly-built broadcasting studio of Radio Fukushima Co., Ltd. The new product has been adopted in openings of the room whose RC (reinforced concrete)-structured interior is shielded with copper foils. As a result, the company has succeeded in restraining the ground electric field intensity at the outside of buildings of electromagnetic waves to less than 90 decibels microvolts per meter. These electromagnetic waves have a capacity of 1,458 kilohertz, an output of 1 kilowatt, and a ground electric field intensity at the outside of buildings of more than 130 decibels microvolts per meter, and are emitted from medium wave broadcasting antennas which stand close together.

For this reason, the company expects that the demand for new products will increase in the field of building, plants related to IC production, etc., as well as partition and opening of buildings such as broadcasting studio, which require the electric field shielding performance.

Fiber Scope for Inspecting Inside of Gas Pipes with a Small Bore Diameter

The Furukawa Electric Co., Ltd. and Osaka Gas Co., Ltd. have jointly developed a flexible type fiber scope, "Fitel Scope (branc name)" used to inspect the inside of gas pipes with a small bore diameter and many bend sections.

Gas supplying pipes are branched off from gas guiding pipes laid in the road, and are connected with gas meters of respective homes. The development of new equipment has been eagerly demanded, because these gas supplying pipes have a small inside diameter of 25 to 40 millimeters, and have some right-angled joints. The new equipment must be thin and tough, must be readily bent, and must withstand the repeating use.

The flexible type fiber scope jointly developed by the above companies is manufactured by fixing 10,000 thin quartz fibers with a outside diameter of 18 micrometers. The right and left of both end faces with a length of 10 meters are completely mated with each other. It is said that fibers other than those of end faces are separated from each other and can withstand the very small repeating bend with a radius of several millimeters.

Also, these companies have developed a coil spring which retains a fiber scope with the high flexibility in order to smoothly insert such fiber scope into gas pipes. In addition, a spherical part is installed on the top of the coil spring so that the object for the fiber scope can be protected and the fiber scope can be smoothly inserted into gas pipes in accordance with the bend of these gas pipes.

20143/9738
CSO: 4306/7518

STATUS, PROSPECTS FOR ALUMINA CERAMICS AS BIOMATERIALS

Tokyo NIKKO MATERIALS in Japanese Sep 86 pp 13-17

[Roundtable discussion with Haruyuki Kawahara, professor emeritus of Osaka Dental College, professor of Asahi University, and director of Clinical Equipment and Material Research Laboratory; Hironobu Onishi, director of Artificial Joint Clinic, Orthopedics Department of National Minami Hospital in Osaka; Yoshiyuki Yamamoto, president's office of Kyocera; and Eiji Tsuji, Special Alloy Group, Metal Department of Osaka Prefectural Research Institute of Industrial Technology]

[Text] Since the theme of this roundtable talk is alumina ceramics as biomaterial, I would like to start with the advantages of ceramics when used as biomaterials.

I am studying the interaction between organic cells and various types of materials. Having examined plastics, metals, ceramics and the composite materials of the three as to their cell-level biological characteristics when used as dental materials, my answer to the question of what the most stable material is when put in the organic environment is that general metals are more stable than plastics and ceramics are more stable than metals in the organic body. For instance, even PMM and HPE (high density polyethylene) which are said to be stable in the organism would have their C-C bond broken and decompose as confirmed by the C^{14} labeled studies.

Such metals as tantalum, titanium, and zirconium which are said to be very stable become active at the boundary with the organic tissue when put in the organic body, and get ionized and melt into the surrounding tissue. This phenomenon is being studied by many researchers using EPA (electron probe analysis).

Highly purified, highly crystallized, and highly sintered ceramic materials in the organic body will not melt into surrounding tissue. It can be said that such ceramics are perfect bio-inert materials, and here lies the rationale for using ceramics as biomaterials. Leaving their mechanical strength aside, we can pick up a number of very safe ceramics through various biological tests. The surface of the ceramics is highly polarized and thus has an affinity with biological tissues and cells. In other words, ceramics have good tissue adhesiveness.

Alumina, the most inert ceramic is highly evaluated as an alternative to hard tissue. This has been demonstrated by clinical data.

On the other hand, there is a view that biomaterials with somewhat bioactive surfaces are acceptable. The bioactive surfaces of apatite and bioglass, metals of Ti, Zr, and Ta and Co-Cr-Mo alloy have a potentiality of chemically binding with the surrounding tissue. The theory is that something melts out from the surface of the material and causes chemical reactions with the surrounding tissue which results in a chemical bond. On the other hand, inactive ceramics such as zirconia, alumina, vitreouscarbon, and silicon nitride show minimal chemical activity though their physical activity is high on the surface. Therefore, even if they are successfully attached to the surrounding tissue, the binding remains at the hydrogen or van der Waals level. Whether inert materials or slightly bioactive materials are desirable, biomaterials must wait for future research and cannot be discussed easily at present.

Leaving this aside, we can cite alumina as a representative bio-inert ceramic at present. Alumina is highly evaluated in international academic meetings relative to bioceramics, and particularly in West Germany a number of researchers are working on alumina as a hard tissue alternative material. (From H. Kawahara's greeting.)

Outstanding Characteristics of Alumina Found

The above having been said, would Dr Onishi, who has handled a number of clinical cases, please start the talk as a user of alumina and many other materials.

Onishi: More than 10 years ago, I was surprised to see in Dr Boutin's laboratory in France artificial joints made of alumina with a small friction coefficient when rubbed together. Prior to that time, I had been very interested in alumina. Before I got to know Kyocera, I had a small commercial plant making experimental materials from alumina. Animal experiments showed that the alumina devices, when compared with metal materials, generate thinner, connective tissue membranes between bones and materials with no membrane at all in some portions. The subsequent elemental analysis of the surrounding tissue identified metal elements when metal was used but no alumina elements were found when alumina was used.

More interesting is that the alumina and polyethylene combination for artificial joints resulted in far less erosion of polyethylene than the metal and polyethylene combination.

The experiment on artificial knee joints using a simulator showed polyethylene erosion against alumina is no more than one-tenth of that against metals. Also important is that alumina's friction coefficient is very low. A high friction coefficient will transmit the force onto the bones and loosen the joints. Based on the findings that the alumina and polyethylene combination causes little erosion, shows low abrasion coefficient, and is bio-inert,

I thought this combination could be applied to artificial joints which do not use bone cement, and to date have expanded the application area to various artificial joints and bones.

To answer the question which may be raised later as to whether alumina is almighty, I cannot say it is all the time. According to research and clinical experiences to date, alumina is not so in some points.

Kawahara: Metal against ceramic shows lower friction coefficient and less erosion than metal against polyethylene which is also demonstrated by Professor Igaki, Engineering Department of Osaka Prefectural University and Professor Sasada, Tokyo Institute of Technology. Similar data have been submitted by Tateishi of Kikaiken (Institute of Machine) as well. There has also been foreign literature on the subject.

The hip joint made of metal and HPE produces scale-shaped erosion flakes from the HPE cap. How about this problem?

Onishi: Right. Scale-shaped erosion flakes are produced. Observation of the polyethylene friction plane reveals completely different shapes of the plane. In the case of metal against polyethylene, the polyethylene surface seems to delaminate into scales, but with alumina against polyethylene, the plane is smooth. Obviously there is a difference in shape.

Kawahara: What shape is the erosion powder through electromicroscopic observation when the combination is metal and alumina?

Onishi: When the combination is alumina and metal, we have tried to observe the shape several times, but without success.

Yamamoto: You said that the erosion against alumina is as small as one-tenth of the erosion against metal. Is this a matter of the surface grinding or in other words, of surface roughness?

Onishi: The surface roughness and surface shape do matter. Even after grinding, metals are uneven on the surface and have a protruding roughness. In the case of alumina, it has a concave roughness, which is meaningful. The wettability will also be involved. It is observed that the concave roughness may provide a desirable condition for lubrication.

Kawahara: Regarding the manufacturing of ceramics, compared with metals, which is more accurate in forming a true sphere? Would Mr Yamamoto, who has worked hard on this point as a manufacturer, please answer this question?

Alumina's Outstanding Accuracy in Sphere Formation

Yamamoto: When we were developing the hip joint in collaboration with Dr Shikida of Osaka University, we compared commercially available metal hip joint balls with ours. While the alumina ball's maximum deviation from the true circle is 0.4 µm, the imported metal bone-head ball's deviation is very large with the maximum of 2.2 µm.

Accuracy results of the ball shape using Newton's Ring showed that the metal ball had several centers of irregular stripes and there were undulations or local deformations on the surface. These types of undulations would positively not work for lubrication, I think.

Kawahara: How about in your laboratory, Dr Onishi...?

Onishi: How bone-head ball accuracy in a ball or circular formation influences polyethylene's erosion was the theme of my research thesis, which was also my doctoral thesis. I received a prize from the International Orthopedics Association for this thesis. The true ball accuracy is very important. At the early stage of development, the true circle accuracy was in the neighborhood of 10 µm or so. With alumina, it is 0.5 µm. Also to be noted, is that the extruded undulations are prone to erode polyethylene.

Yamamoto: Since surface roughness of alumina is 0.04 µm or less, we can realize with this material a plane as smooth as a mirror, so called mirror grinding. Metals cannot achieve this as alumina can. As Dr Onishi previously said, the ground surface of alumina is concave and barely scrapes and erodes soft polyethylene. Another consideration is that the alumina crystal has oxygen ions in lattice cubic alignment, making its surface polarized and forming a stable water membrane. I wonder if this may result in lubrication, low erosion, andlow friction.

Onishi: The bone-head removed from the organic body is heavily marred and worn out on the surface when the material is metal. When it is made of alumina this is not observed. Thus alumina's performance is far better in the sliding portion than metals.

Kawahara: Apart from the consideration as to which alumina or metal can be made more accurate in terms of finished formation accuracy, it should be considered that the mars on the surface of the in-vivo artificial bone-head represent a local corrosion phenomenon where perhaps body fluid, joint fluid, and mechanical stimuli are intricately involved. Alumina is inert in the organic body and thus rarely causes or develops mars. In addition, it may be that the highly polarized alumina is prone to adsorb substances from the body fluid and to retain the body fluid in the bone-head cap all the time. The use of metal bone-head is said to have failed in many cases.

Onishi: The erosion flakes, whichare produced in large volume, react with the bone and destroy the bone, and the artificial joint quickly loosens.

Kawahara: By loosens, do you mean the flakes accumulate in the joint cavity?

Onishi: Not in the joint cavity but between the artificial material and the bone. Because of this the bone is steadily destroyed and replaced with granulated or necrotic tissue.

Kawahara: Does the metal enter the bone in the form of a colloid?

Onishi: It is polyethylene erosion powder. Metals do not erode so much unless they are rubbed against metals.

Kawahara: The cause being not metal powder but polyethylene flakes, the problem is considerably serious? I think it is biologically very important to see what is produced when the in-vivo plastic material is eroded.

Onishi: They could be called scales, since cells promptly injest them....

Kawahara: Are the scales larger than the cells?

Onishi: They come in various sizes.

Kawahara: The erosion is an extraordinary phenomenon where polyethylene could be depolymerized. Polyethylene may become seriously toxic when turned into monomers. Polymers in their colloid state have special biological actions. Further detailed examinations should be desired....

Yamamoto: With metal materials, the HDP erosion rate seems to be considerably high--100 μm per year.

Onishi: It is difficult to measure the rate because creep deformation is included. We measure volume reduction only. This includes the creep deformation to a considerable extent.

Kawahara: What we are discussing is polyethylene isn't it?

Onishi: Right.

Kawahara: Alumina seems to have almost no influence.

Onishi: With alumina, polyethylene reduces but without causing erosion flakes. I think the reduction is due to the creep deformation.

Kawahara: Roughly, how much do you think the erosion contributes to the clinical failures? What percentage of the failed cases of metal-polyethylene combination is attributable to the erosion flakes?

Onishi: This is very difficult to answer because the thickness of the polyethylene is involved. When the polyethylene is thinned, it causes creep deformation and wear increases. Another factor is the quality of the polyethylene. In the early stages of our trials, the quality of the polyethylene itself was poor. Polyester which can be disinfected by autoclave was used in place of polyethylene 12-13 years ago, but all clinical cases which employed this showed rapid erosion of the polyester and significant destruction of the bones. The material was imported and used in Japan. There are many patients also suffering there.

Kawahara: Is it difficult to identify how much is due to erosion?

Onishi: This is difficult to identify. Very difficult.

Kawahara: Is it seldom that such a phenomenon appears with the polyethylene and alumina combination?

Onishi: It needs prolonged observation.

Kawahara: How many years have you been working on it?

Onishi: We're in the 9th year now. Only the ceramic and polyethylene combination is used in other countries so it is impossible to see the difference.

Another problemin the early days was technical skill. Over a long period of time, even though the joint has not come loose as a whole, local X-ray examination shows absorption, which gradually increases. We find it filled with granulation tissue when the site is incised for some other problem. It is a reaction caused by the erosion flakes. Taking this into consideration, the alumina vs polyethylene causes this less than the metal vs polyethylene.

Yamamoto: From the first, I commercialized the steel hip-joint which uses alumina for the ball and high density polyethylene for the cap, while receiving basic and clinical guidance particularly from Dr Onishi. Fortunately, there have been no problems of erosion or loosening as have been discussed here.

Kawahara: Having conducted table work (test tube study) for material evaluation over the last 30 years, I had a big question about the selection of the parameters. Therefore, I started to put emphasis on clinical evaluation where the materials can be studied comprehensively. I feel that a true evaluation is not possible unless medical materials are sent back to their origin to performthe analysis once again. For example, take the erosion test of polyethylene vs metal and polyethylene vs alumina. The data would be very different depending on whether thetest was conducted in dry conditions or not, or what kind of lubricant is used. Preferably the test should be performed using not a simple saline but a lubricant close to the body fluid and the environment as similar as possible to the conditions where the materials are clinically used. Thus, the development of a suitable simulator should be promoted.

Many researchers in various fields are conducting in vitro tablework. They are trying to set the standard for implantable materials such as those for the hip joint and the artificial heart. Intensive efforts are being made to establish the standard for ISO-150, but it is hard to make the decisive one. As to the ISO-106 (dental materials), dominant view is that the only possible way is through a usage test.

The usage test means to use animals under the same conditions as clinical application in order to standardize the material. Data from this test, being widely dispersed, cannot be said to be a statistically accurate evaluation. Thus, setting biological standards for dental materials is a difficult task. Also regarding the evaluation method for artificial joint materials, many different researchers are reporting different methods. Is there any decisive one?

Onishi: I think not.

Kawahara: Then after all, are we to employ the usage test? We cannot use humans for experiments. I guess here lies the difficulty in evaluating the biomaterials.

Onishi: Right. It is necessary to standardize the procedures. We are all conducting the test using different simulators under varied conditions. The conditions change from the first to the second test.

Kawahara: For this area, the Ministry of Health and Welfare does not have funds and the Ministry of International Trade and Industry is not paying attention. It means that an important portion is entirely missing. That is why good medical devices developed by individual Japanese or corporations will take a minimum of 5 years before commercialization. Thus, when they are approved, new materials have been commercialized ahead of us. While the MHW seems to give approval easily to foreign products if supported with foreign data, Japanese products cannot get U.S. approval so easily. This is unfair. No time should be wasted. MHW, Medical Association of Japan, business corporations, and other relative organizations should cooperate to promptly establish a unique system as a counterpart of ABU (United States), DI (West Germany), and NION (three North European countries) so that medical devices canbe quickly assessed.

Onishi: Regarding the polyester material I talked about, it was approved without difficulty because it was a European product.

Kawahara: In Japan we have to submit clinical study protocol before commercialization. Depending on the type of product, we have to wait several years at this stage. Even after the "go" sign is given, we must monitor 30 cases in public facilities and 60 cases in other facilities for a minimum of 3 years after the operations are conducted.

Yamamoto: Let me explain our experience. First we have to conduct basic evaluations as to whether this material is organically compatible. For this purpose we conduct tests prescribed for medical devices to decide whether the material is pyrogenic or hemolytic and can be used in the body.

The next problem is design. The orthopedic products need to be supported with data that show biomechanical strength. Take the hip joint for instance. We need to determine the strength required for the ceramic ball, two types of strength--static strength and dynamic strength. This is done by imposing a 1 ton load and repeating it 10 million times in wet conditions to determine the weight at which the ball ultimately breaks. At first, we did not know how many tons should be used. We just assumed a human weight of 50-60 kilos and thought that five to six times that would do. But it turned out that a heavier load is required to be internationally used. At present the Japanese domestic requirement is 1 ton, but in the United States they are using more than 2 tons and testing 10 million times. Under the circumstances, our company is currently employing a weight of no less than 3 tons. After generating the biomechanical data with considerable allowance in terms of

strength, we submit the application for clinical trials, which requires 30 cases from 2 facilities, respectively.

In some facilities the surgical operations take place frequently enough to collect 30 cases quickly. But some facilities have large numbers of patients while others do not. In facilities with small numbers of patients, it may take up to 2 years. After the devices are implanted in the body, we must follow-up the cases. Upon compilation of the data we file the application. after 1 year the document is examined by the authorities for approval. Side-effect reporting is necessary afterward. The 3 years Dr Kawahara cited comprise the side-effect reporting period. This is to have many nondesignated medical facilities use the devices to generate further data under tentative approval. For this purpose, we identify the facilities to be involved for the 3-year period, work out the items to determine the side-effect incidence, and set the number of cases to be followed. We submit the protocol covering these things and if the ministry considers the protocol satisfactory to generate sufficient data on side effects, the approval is given for us to monitor the cases for 3 years. According to our calculations, it takes 7 years from when we decide the material is to be used until the formal approval is given assuming everything progresses smoothly. Including the 3 year side-effect reporting period, it takes 10 years. If no problems are observed, the device is given approval and is designated as being a highly reliable product.

In the meantime, however, new design products will appear.... Apprehension arises because the product life-cycle is becoming extremely short these days. Basically, we should statistically compile the cases over a long period of time to establish an evaluation, but realistically design changes do not allow that time. The tendency is particularly conspicuous with imported products, I believe.

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ELECTROMAGNETIC BONDING FOR PLASTICS DISCUSSED

Tokyo KINO ZAIRYO in Japanese Sep 86 pp 28-40

[First paragraph is editorial introduction]

[Text] The internal heating method of adhesives is attracting attention as an efficient quick-bonding method. It is a method which selectively concentrates energies such as ultrasonic waves, high frequency, microwaves, and vibration. The types and characteristics of the bonding method by internal heating will be briefly discussed in this text, as will the electromagnetic bonding of plastics in which there is special interest. An introduction will be given of its principles, outline, characteristics, performance, application examples, and future developments.

1. Introduction

Quick-bonding is one of the ultimate objects in bonding. Various methods are studied, developed, and put to practical use as approaches to quick-bonding. Since bonding by setting takes place, for example, in solvent and emulsion adhesives due to the solvent and dispersion medium evaporating or being absorbed by the adherent, bondings such as the high solidification of solid parts and spraying of two fluids (honeymoon adhesive) are performed. The development of hot-melt type adhesives in which adhesive polymer is applied in a hot molten condition and is hardened quickly by cooling is also notable. Chemical reaction type adhesives harden by the chemical reaction (polycondensation, radical polymerization, ionic polymerization, etc.) of constituents. However, the reaction speed and shelf-life are generally reciprocal and for performing quick-bonding, there are those that are subjected to separation of the catalyst (separation into two fluids or becoming a primer) during storage, or those that are made to contain a potential type adhesive in advance and made to start reaction by means of external energies such as heating, light irradiation (UV hardening), and electron beam irradiation (EB hardening).

In the case of heating, various internal heating methods for quick-bonding have been developed recently in addition to the external heating by general ovens. High-frequency dielectric heating, microwave heating, and electromagnetic heating (high-frequency induction heating) are recently developed internal heating methods and efficiently heated bonding becomes possible in a short time by converting the electric energy into thermal energy and concentrating it on the bonding part. Moreover, there is also the method of

concentrating mechanical energy on the bonding part and converting it into thermal energy as seen in ultrasonic deposition, vibration bonding, and spin bonding. In any event, there is no time loss due to heat transfer and useless energy for heating the atmosphere is not required as heat is generated from the interior of the adhesive or directly from the bonding part. In this text, a general statement will be made on bonding by these internal heating methods centered around electromagnetic bonding, which has been attracting attention recently.

2. Bonding Method by Internal Heating

2.1 Ultrasonic deposition

In ultrasonic deposition, electric energy is converted into a vibration (mechanical energy) up to 40 kHz. This energy is transferred to the bonding part via the horn, concentrated at the bonding part, and converted into frictional heat, and bonding is performed. The vibration direction against the bonding surface is in a perpendicular direction and as seen in the case of similar type plastic bonding, there is the deposition method which does not use adhesive and the method that does. The low-cost quick-bonding method for small-size plastic parts is widely used for bonding disposable lighters, automobile parts, toys, and stationery. On the other hand, in crystalline plastic and in transfer deposition where the distance between the phone and bonding part is more than 6 cm, there is quite a restriction in the adherents as the ultrasonic vibration is absorbed (Table 3). Moreover, there are also problems such as the difficulty of bonding different kinds of materials and its application to large-size parts.

2.2 Vibration bonding

Vibration bonding is also called vibration welding. The adherents are mutually vibrated mechanically at 100 to 240 Hz and bonding is done by the generated frictional heat. The amplitude is 1 to 4 mm and is great in comparison to ultrasonic wave. Technical know-how is involved in the handling method of the jig for holding all the parts with the jig and performing pressurization and vibration. This know-how has already been studied and put to practical use in large-size parts. However, the bonding of a three-dimensional curved surface is not yet possible. In bonding similar to this, there is spin bonding for parts possessing a round bonding part.

2.3 High-frequency dielectric bonding

Together with the microwave bonding and electromagnetic bonding, mentioned later, high-frequency dielectric bonding uses a high frequency for heat bonding. The high frequency is classified as shown in Table 1 by frequencies, and the high-frequency dielectric bonding is mainly used in the shortwave wavelength of several MHz to several tens of MHz. It is necessary that the adherent or adhesive be a dielectric substance, and the most famous application is the high-frequency welder for soft PVC. The principle of this bonding utilizes the fact that the dielectric loss coefficient ($\varepsilon \cdot \tan \delta$) of soft PVC, urethane, and nylon is especially large among plastics, and by

Table 1. Classification of Frequencies

Frequency (Hz)	Wavelength (m)	Symbol	Designation	Heating use
~ 30 k	10^4 ~	VLF	Longwave	
30 k ~ 300 k	10^3 ~ 10^4	LF	Mediumwave	
300 k ~ 3 M	10^2 ~ 10^3	MF		High-frequency induction heating
3 M ~ 30 M	10 ~ 10^2	HF	Shortwave	High-frequency dielectric heating
30 M ~ 300 M	1 ~ 10	VHF	Ultra-shortwave	
300 M ~ 3 G	0.1 ~ 1	UHF	Microwave	Microwave heating
3 G ~ 30 G	0.01 ~ 0.1	SHF		
30 G ~ 300 G	0.001 ~ 0.01	EHF		

flowing a high-frequency current through the adherent itself, heat is generated by the collision and friction of molecules (Figure 1). The calorific value is indicated by the following formula:

$$P = K \cdot \varepsilon \cdot \tan\delta \cdot f \left(\frac{V}{d}\right)^2$$

where, P: Calorific value (W/cm^3)
K: 0.56×10^{-12}
ε: Dielectric constant
$\tan\delta$: Dielectric loss tangent
f: Frequency
V: Voltage between electrodes
d: Distance between electrodes

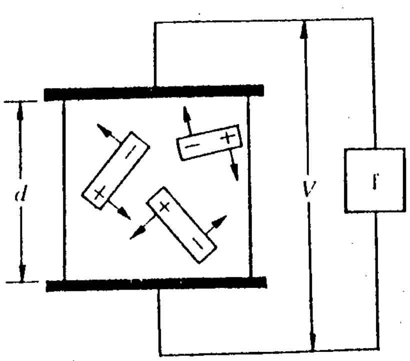

Figure 1. Principle of High-Frequency Dielectric Heating

Uniform heating is also possible on the surface and interior of a thick adherent in high-frequency dielectric heating and, moreover, local heating is also possible according to the electrode position and quality of the material. However, there are defects such as the bonding speed which is slightly slow, high watt consumption, dielectric breakdown and spark generation when the voltage between electrodes is raised for increased bonding speed, and difficulty of heating the electric conductor. Besides the bonding of soft PVC, it is used for end forming assembly of wood and bonding glued laminated wood when using water type adhesives, andis also utilized for bonding furniture, pianos, guitars, and sporting goods or interior finishing materials of automobiles by using a film type hot-melt adhesive.

2.4 Microwave bonding

The principle of microwave bonding is approximately the same as that of high-frequency dielectric bonding. However, electrode plates are not used and a microwave with a higher frequency (industrially in the neighborhood of 915 MHz and 2,450 MHz) is irradiated on the bonding part. There is the open-type and the waveguide system equipment, and an electronic cooking range can be used experimentally. The microwave reflects on metals, passes through polyethylene (PE), polypropylene (PP), and Teflon with a small $\varepsilon \cdot \tan \delta$ but generates heat when passing through materials with a large $\varepsilon \cdot \tan \delta$. While microwave heating has a fast heating rate and is applicable to complicated shape adherents in which electrodes cannot be used, it also has problems such as the reflection problem of the microwave according to the type of adherents and the problem that the microwave does not permeate up to the adhesive (the greater the frequency and $\varepsilon \cdot \tan \delta$, the smaller the permeation depth). Its main use is the continuous vulcanization of rubber, and recently developments in the wood-bonding field such as the bonding of the corner parts of plywood by the water type adhesive and the bonding of glued laminated wood have been promoted. Moreover, since microwave exerts an adverse effect on the human body, a device becomes necessary in the facility aspect for microwave leakage.

2.5 Electromagnetic bonding (high-frequency induction bonding)

When magnetic material such as iron is placed in an electromagnetic induction atmosphere (within a high-frequency magnetic field), heating is done in a short time by the hysteresis loss of the magnetic material and the joule heat caused by the eddy current. In application to electromagnetic bonding, there is a case where the adherent is a magnetic material (metal) as shown in (a) of Figure 2 and a case where the adherent is a nonmagnetic material and a strong magnetic material is contained before bonding as shown in (b) of Figure 2. The former is widely used for bonding in canning and the latter is the electromagnetic bonding mentioned in this text. Heating by the hysteresis loss of the magnetic material is shown by the following formula:

$$P_h = \eta \cdot f \cdot B_m^{1,6} \cdot V$$

where, P_h: Calorific value by hysteresis loss (W)
η: Hysteresis coefficient

f: Frequency
B_m: Maximum magnetic flux density (Wb/m^2)
V: Volume of heating material (m^3)

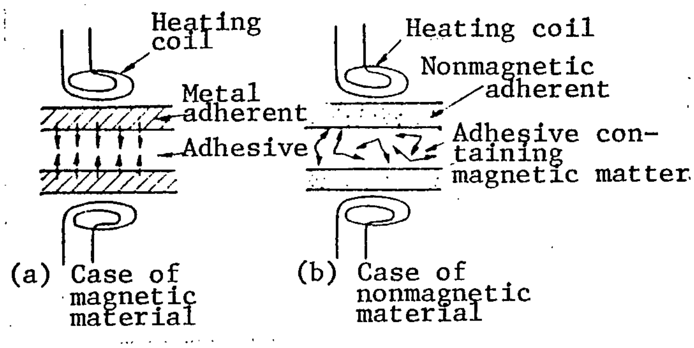

Figure 2. Principle of High-Frequency Induction Heating

Moreover, the joule heat caused by the eddy current is indicated as follows for practical use.

$$P_c = K \cdot N^2 \cdot I^2 \sqrt{\rho \cdot \mu \cdot f}$$

where, P_c: Joule heat caused by eddy current
K: Specific constant
N: Windings of coil
I: Coil current
ρ: Specific resistance ($\Omega \cdot$ cm)
μ: Effective permeability

As shown in Figure 3, the higher the frequency, the greater the calorific value. On the other hand, however, it is known that the distance the magnetic flux reaches will become smaller as the frequency becomes higher and an unequal heating of the adhesive is likely to occur as it is susceptible to local heating. Figure 4 shows an example of the heating rate of various metals used as magnetic materials. The heating speed of iron, which is a strong magnetic material, is the fastest and the heating rate of copper with weak magnetism is slow. The relation between the distance of the heating coil and adherent and the heating rate is shown in Figure 5.

3. Outline and Characteristics of the Electromagnetic Bonding System

The electromagnetic bonding system consists of a high-frequency oscillator, heating coil, jig, clamping press, and adhesive containing a strong magnetic material. An example of the bonding system is shown in Figure 6. The main components of an adhesive are the matrix with an adhesive property and a strong magnetic material. A compatible resin of the same family as the adherent or a resin with an adhesive property selected according to adherents

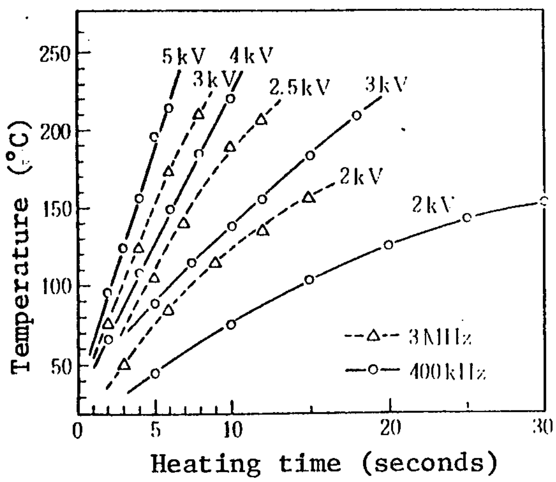

Figure 3. Frequency, Applied Voltage, and Exothermic Rate (Magnetic material: Iron, α = 4.0 mm)

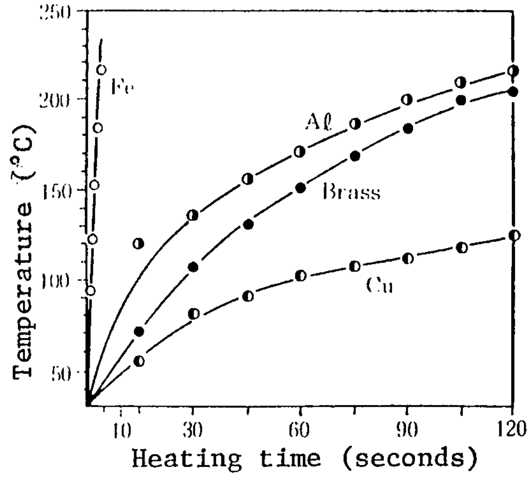

Figure 4. Comparison of Exothermic Rate by Types of Metal (Frequency 400 kHz, output 5 kV, pancake coil)

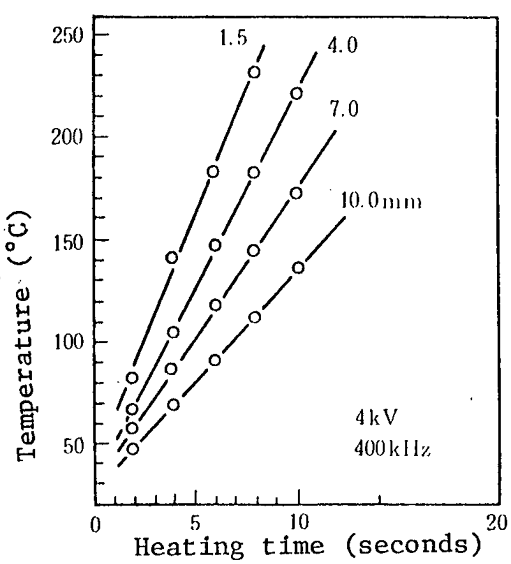

Figure 5. Distance Between Coil and Adherent and Exothermic Rate (Magnetic material: Iron)

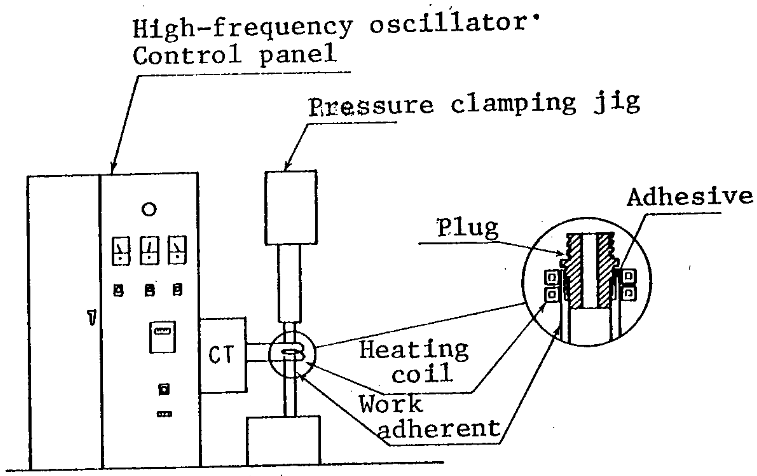

Figure 6. Configuration of Electromagnetic Bonding System

(hot-melt adhesive, heat-hardening type adhesive, etc.) is used for the matrix. Iron alloys such as those of iron and stainless steel, metals, or alloys such as those of aluminum, nickel, and cobalt, and powders such as ferrite are used as strong magnetic materials. Bonding characteristics such as bonding strength and durability are decided by the careful selection of the matrix, and the bonding rate is decided by the suitable matching of the type and shape of the strong magnetic material and the high-frequency condition. The shape of the adhesives used are sheet form, film form, tape form, strand form, molded form matching the structure of the bonding part, and paste form. When these adhesives are inserted between the adherents and placed in the electromagnetic induction atmosphere (heating coil interior) while lightly compressing, the adhesives themselves perform internal heating due to the rapid heat generation of the magnetic materials and by the processes of melting, wetting, and cooling of the adhesive matrix or by chemical reaction, and bonding is completed in a short time (Figure 7).

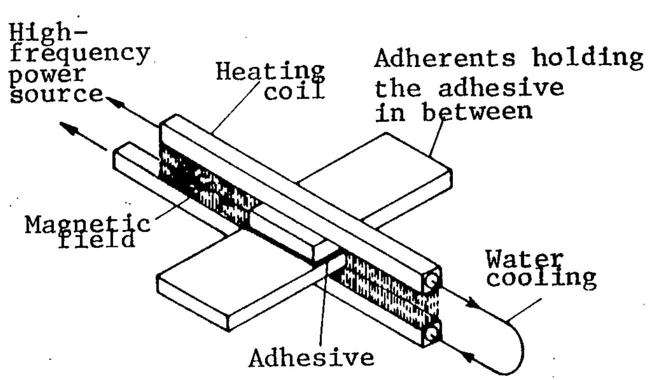

Figure 7. Electromagnetic Induction Bonding

The high-frequency oscillator is selected by the size and shape of the bonding part, bonding rate required,and the type of adhesive. However, the output from several kw to several hundreds of kw and the frequency from several hundreds of kw to several MHz are generally suitable. The heating coil is manufactured by matching the shape of the adherent, but basically there are the single turn type, multiturn type, hairpin type, and pancake type as shown in Figure 8. All of these types are made of copper and are of such a structure that cooling water can pass through the coil interior to prevent heating of the coil itself. Since the heating efficiency becomes higher as the distance between the heating coil and adhesive becomes closer, the coil design together with the uniformity of the magnetic field is a vital point of this system.

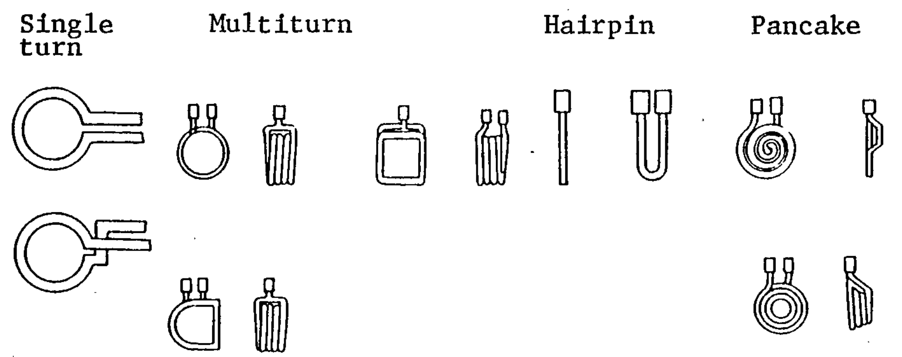

Figure 8. Types of Heating Coil

A listing of the characteristics of the electromagnetic bonding system is as follows:

(1) Quick-bonding in several seconds to several tens of seconds is possible due to the internal heat generation of the adhesive.

(2) The structural bonding of thermoplastic resins, including PE and PP, is possible.

(3) Bonding of different kinds of materials is possible by the selection of the adhesive matrix.

(4) Since the physical and chemical properties of the bonding part do not differ practically from those of the adherent, it can be used under the same conditions as the adherent in many cases and an airtight seal excelling in heat resistance, water resistance, and durability can be made.

(5) Pretreatment and primer treatment are not necessary, handling of the adhesive is easy as it is a formed item, and the working environment is not deteriorated.

(6) Automation of the bonding process is easy to perform and is optimum for a mass production line.

(7) The structural freedom of the adherent such as type, shape, and size are great in comparison to ultrasonic deposition and vibration bonding.

(8) The adherent is not damaged due to the rapid internal heat generation.

Table 2. Comparison of Bonding Technology

	Electro-magnetic induction	High frequency dielectric	Hot blast deposition	Ultra-sonic wave	Vibration	Spin	Hot platen deposition
Bonding of same kind of materials	5	1	5	3	4	5	5
Bonding of different kinds of materials	4	0	1	3	2	3	3
Polyolefin bonding	5	0	5	3	4	4	5
Airtightness	5	4	4	4	3	3	4
Bonding strength	4	4	3	3	5	4	4
Fitting shape (large)	5	3	5	1	5	0	2
" " (small)	5	5	5	5	0	4	4
Complicated joint	5	4	4	3	1	0	3
Simple joint	5	5	5	5	5	4	5
Bonding rate	5	3	3	3	3	4	4
Automation	5	3	0	5	1	5	3
Equipment cost (per output)	5	4	4	5	3	5	3
Variable cost	1	5	1	5	5	5	5
Cycle	3	3	1	5	3	4	2
Process freedom	4	1	5	4	2	3	2
Residual stress	3	5	4	1	1	1	2
Appearance	5	1	1	3	2	2	4
Reliability	4	4	5	3	3	2	3
FDA fitness	3	5	5	5	5	5	5
Persons required	4	3	1	4	3	5	3
Energy consumption	3	2	3	5	2	4	1
Totals	88	65	70	78	62	72	72

0: Unfit 5: Optimum

Table 2 shows a comparative study of the electromagnetic bonding system with the usual internal heating method, and although they have their advantages and disadvantages, it can be understood that the electromagnetic bonding system is generally superior.

4. Performance of Electromagnetic Bonding

The electromagnetic bonding system is capable of performing bonding in seconds. Figure 9 shows the oscillating time, adhesive temperature, and bonding strength in PP bonding. The temperature rises up to about 170°C by the oscillation of about 1 second and the material breaking strength of PP is obtained by slight cooling.

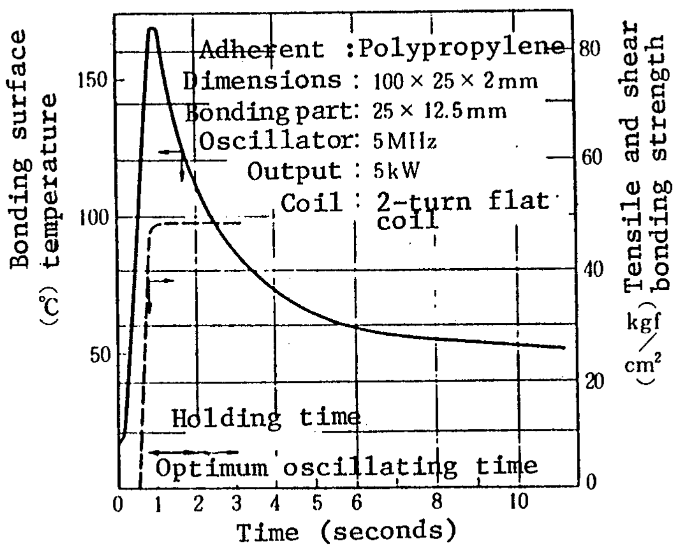

Figure 9. Oscillating Time, Temperature, and Bonding Strength

By selecting the proper bonding matrix, the bonding of practically all materials such as thermosetting resin, metal, ceramics, wood, and paper, as well as the structural bonding of thermoplastic resin, are possible. Table 3 compares the propriety on bonding the representative plastics with the high-frequency dielectric bonding and with the ultrasonic deposition (transfer deposition). Table 4 shows the bonding strength of various materials (the same type of materials and different types of materials). The material breaking strength also for composite materials such as various engineering plastics and fiber-reinforced plastics, as well as for the polyolefin resin and polyolefin elastomer of PE and PP, has been obtained. Figure 10 shows the possible combination of different types of material bonding. Although there is the complexity of having to use adhesive in comparison to ultrasonic deposition and vibration bonding, the application range of different types of material bonding is extremely wide, and in the future a further expansion of the objective range can be expected by the application of compatible technology, polymer alloy technology, and surface chemistry technology.

An example of the heat-resisting property is shown in Figure 11. The adherents are glass-fiber reinforced PP (azudel or X-sheet) mutually and PE, PP, and metals. All data are of the material breaking strength and can be used under an environment of the same degree as the adherent. Table 5 shows the water resisting property.

Table 3. Fitness of Electromagnetic Bonding Adherent

	Electromagnetic induction	High-frequency dielectric	Ultrasonic deposition (transfer deposition)
PVC (soft)	Δ	O	X
PVC (hard)	O	O	Δ
Vinylidene chloride	O	O	X
Polyethylene	O	O	X
Polypropylene	O	X	X
Polystyrene	O	X	O
ABS	O	Δ	O
AS	O	X	O
Metaacryl	O	Δ	O
Polycarbonate	O	Δ	O
Nylon 6, 66	O	O	X
Polyester (thermoplasticity)	O	X	X
Polyacetal	O	X	O
Denatured PPO	O	X	O
Ionomer	O	Δ	X
EVA	O	O	X
Urethane	O	O	X
Ethylene trifluoride	O	X	X
Epoxy	O	X	X

Table 4. Bonding Strength of Various Materials

	Bonding method	Adherent	Bonding strength (kgf/cm^2)
Same kind of materials	Tensile and shear bonding strength (JIS K 6850)	Polyethylene	* 42
		Polypropylene	* 47
		Glass fiber-reinforced polypropylene	* 86
		PBT	* 42
		Nylon 6	* 60
		Filler reinforced nylon 6	*104
		ABS	* 73
		Hard PVC	* 75
		Polycarbonate	* 58
		PMMA	* 43
		FRP (glass fiber-reinforced unsaturated polyester)	*120
		Steel	320
		Aluminum	315
		Stainless steel	288
		Brass	256
		Japanese beech	*115
		Japanese cedar	* 70
	Flexural bonding strength (JIS K 6856)	Glass resin reinforced polypropylene	*62 kgf
Different kind of materials	Tensile and shear bonding strength (JIS K 6850)	Polypropylene/steel	* 53
		" /aluminum	* 54
		" /stainless (SUS 304)	* 52
		" /brass	* 52
		" /FRP	* 40
		" /glass reinforced " polypropylene	* 47
		Polyethylene/steel	* 48
		" /aluminum 9340	* 45
		" /stainless (SUS 304)	* 45
		Polycarbonate/MMA	84
		" /ABS	52
		" /FRP	55
		ABS/FRP	73
		" /steel	* 87
		" /stainless (SUS 304)	* 90
		FRP/steel	96
		" /aluminum	55
		" /stainless (SUS 304)	76
		PMMA/steel	*130
		" /brass	* 90

*Base metal rupture

	Adherent	17 Wood	16 Brass	15 Stainless	14 Aluminum	13 Steel	12 ABS	11 PMMA	10 PVC	9 FRP	8 Polycarbonate	7 Nylon 6	6 Polyolefin elastomer	5 EPDM	4 PBT	3 FR-polypropylene	2 Polypropylene	1 Polyethylene
1	Polyethylene	○	◎	◎	◎	◎	○		○	○		○	◎					◎
2	Polypropylene	○	◎	◎	◎	◎				○		○	◎			◎	◎	
3	FR-polypropylene		◎	◎	◎	◎				○		○	◎			◎		
4	PBT	○	◎	◎	◎	◎	○	○	◎	○	○				◎			
5	EPDM												∧	∧				
6	Polyolefin elastomer	◎	◎	◎	◎	◎				○		○	◎					
7	Nylon 6											◎						
8	Polycarbonate	○	○	○	○	○	◎	○	○	○	◎							
9	FRP (unsaturated polyester)	◎	◎	◎	◎	◎	◎	○	○	◎								
10	PVC	◎	◎	◎	◎	◎			◎									
11	PMMA	○	◎	○	○	◎	○	◎										
12	ABS	○	○	○	○	○	◎											
13	Steel	◎	○	○	○	○												
14	Aluminum	◎	○	○	○													
15	Stainless (SUS304)	◎	○	○														
16	Brass	◎	○															
17	Wood	◎																

◎ Base metal rupture
○ Good bonding (more than 30 kgf/cm^2)
∧ Bonding possible

Figure 10. Adhesive Property of Different Kinds of Materials

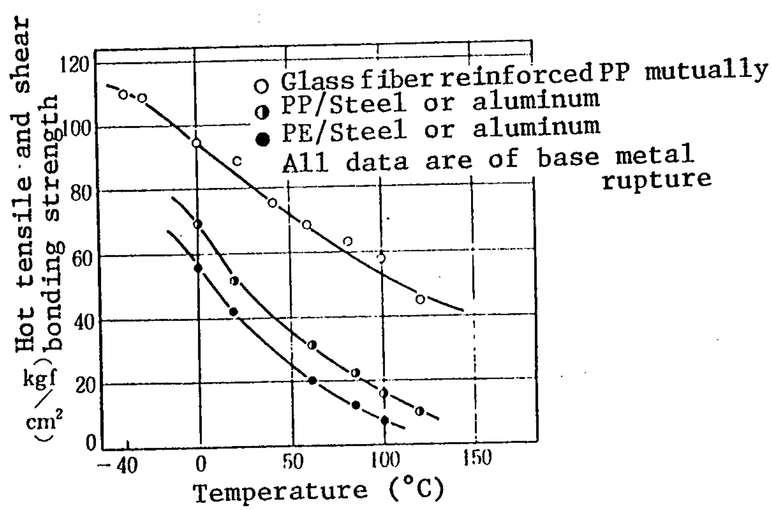

Figure 11. Heat-Resisting Property (Hot Bonding Strength)

Table 5. Water Resisting Property
Adherent: Glass fiber-reinforced polypropylene

Condition	Tensile and shear bonding strength (kgf/cm)
Undipped (control)	* 86 (100 percent)
Dipped in 20°C water for 3 days (JIS K 6857)	* 92 (107 percent)
Dipped in 20°C water for 30 days	* 79 (92 percent)
Dipped in 100°C water for 4 hours	* 78 (91 percent)
Dipped in 100°C water for 72 hours	* 63 (73 percent)

*Base metal rupture

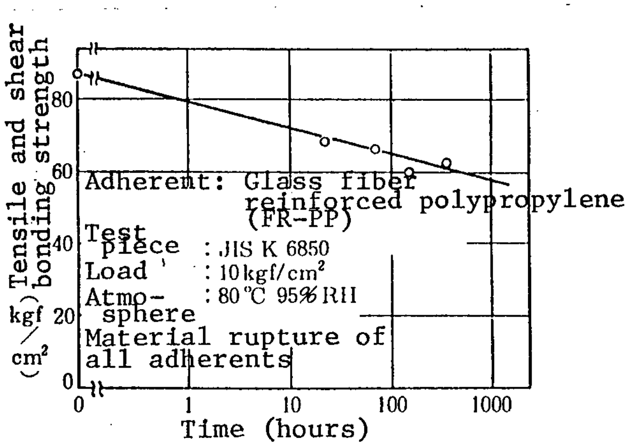

Figure 12. Dead Load Test of FR-PP

Figure 12 shows the dead load test of azudel or X-sheet mutually. The dead load test performs an atmospheric exposure at a high temperature and high humidity of 80°C and 95 percent RH in a creep condition with stress placed on the adherent, and this is one of the severest tests performed for durability and reliability of structural adhesives. After exposure of 240 hours, material rupture was indicated but no drop in strength could be observed in the adhesive itself.

Table 6 is an example of the epoxy electromagnetic induction adhesive. A sufficient bonding strength was obtained by 2 to 3 minutes of heating and room temperature curing due to the internal heat generation of the adhesive, and the reduction of the heating time to about one-tenth was possible in comparison to the atmospheric heating by an oven. Altogether, the energy-saving effect is extremely great as all parts do not have to be heated.

Table 6. Epoxy Electromagnetic Induction Adhesive

Heating method	Bonding time	Tensile and shear bonding strength (kgf/cm^2)
Electromagnetic induction heating	30 seconds 120 seconds 180 seconds	Unhardened 88 120
Atmospheric heating	30 minutes 60 minutes	112 129

Adherent: FRP (glass fiber-reinforced unsaturated polyester)
Bonding method: JIS K 6850 (tensile and shear bonding strength) lap 12.5 mm
Heating conditions: Induction heating Output 0.12 kw
Frequency 400 kHz
Coil 2-turn flat coil

Atmospheric heating 80°C thermostat

Strength measurement: Bonding $\xrightarrow{\text{Directly after}}$ Heating $\xrightarrow{\text{Left to cool for 30 minutes at room temperature}}$ Measurement

5. Bonding Structure Design

As already shown in Table 2, the structure of the bonding part of the electromagnetic bonding system has great freedom in shape compared to ultrasonic deposition and vibration bonding. In other words, the bonding of three-dimensional curved surfaces is also possible for small to large articles. However, since there is a necessity of bringing the distance between the coil and adhesive as close as possible for heating efficiency, it is important to study the designs suited for bonding the coil design, etc., from the stage of parts designing. Figure 13 shows an example of the position relation between the adherent and coil as an example of the bonding structure. Continuous bonding as shown in Figure 14 is also possible in the case of bonding with a large plane.

When airtightness of the bonding part is required or the bulging of the adhesive is improper, it is preferred that it be made of spigot structure as shown in (b) to (3) of Figure 15. This structure is also effective for promoting the efficiency of the adhesive loading operation. It is optimum that the adhesive sectional area of the spigot structure be 1.02 to 1.08 times the space sectional area of the bonding part.

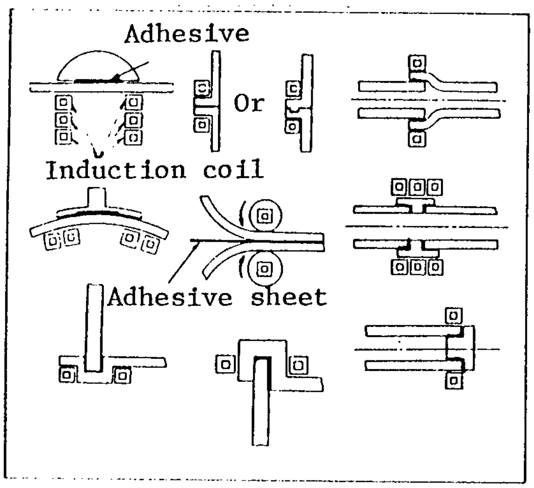

Figure 13. Examples of Bonding Structures

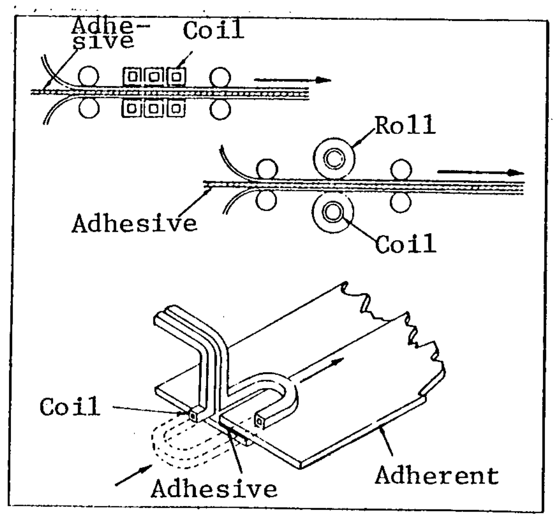

Figure 14. Continuous Bonding

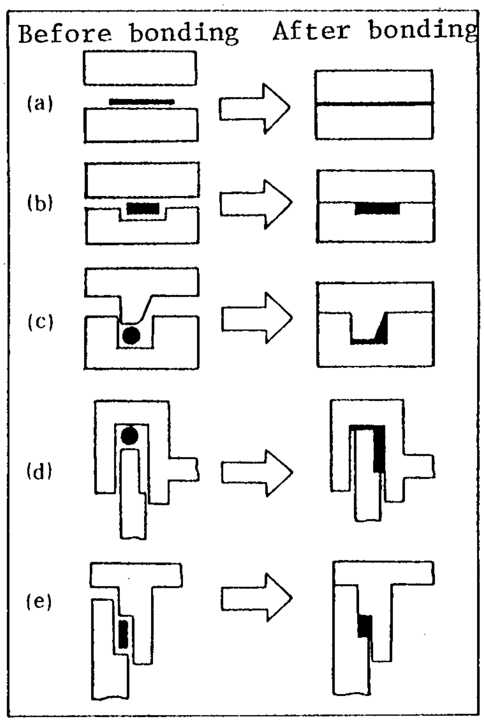

Figure 15. Examples of Bonding Structure

6. Applications of the Electromagnetic Bonding System

The applications of the electromagnetic bonding system can be considered to be extremely great. Especially as the structural bonding of polyolefin has become possible, it can be considered that the material conversion to polyolefin

resin for automobile parts, electrical equipment parts, and housing, which could not be conventionallyused due to bonding difficulty, will suddenly progress. In the United States, for the reason that polyolefin resin contributes to making automobiles light weight and that the design freedom is great, an Azudel-made bumper beam which has been bonded by the electromagnetic induction method has already been put to practical use on the GM Calvert (Figure 16). Moreover, it has been used for bonding reinforcing agents (azudel mutually) for providing rigidity to the bed flooring of stationwagons. Besides these, there are application examples such as the HDPE-made metallic cap part of drum cans from 5 to 55 gallons (Figure 17), airtight seal bonding of PP-made cosmetic (mascara) containers (200 each/minute, Figure 18), and bonding assembly of foamed HDPE-made speaker cabinets (Bose Co., Figure 19).

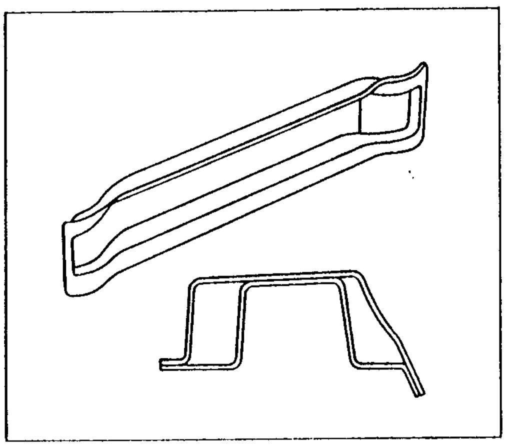

Figure 16. Azudel-Made Bumper Beam

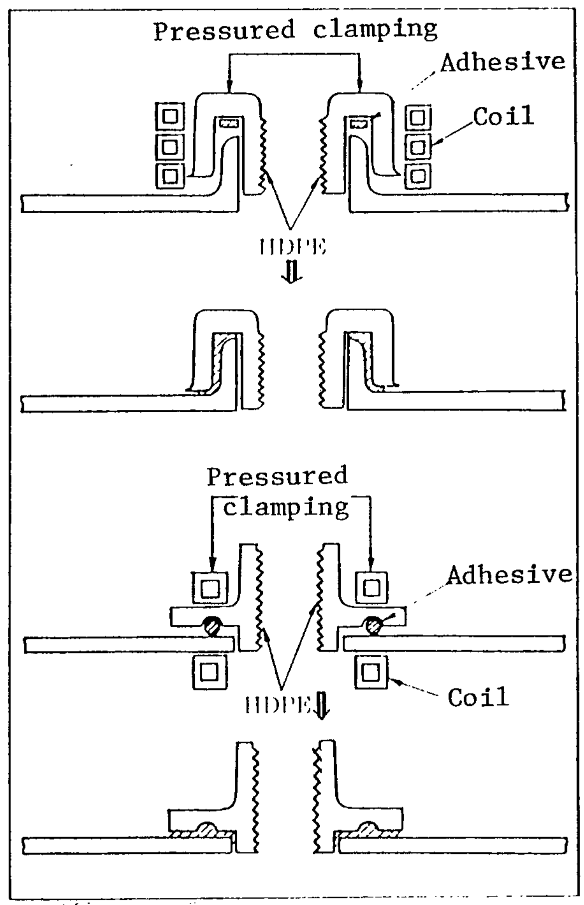

Figure 17. Bonding Examples of Polyethylene-Made Drum Metallic Cap

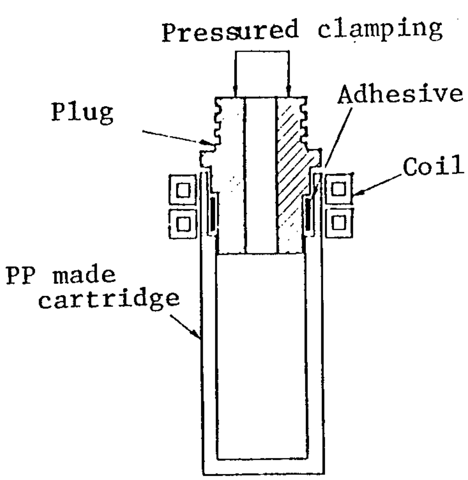

Figure 18. Airtight Seal Bonding of PP-Made Mascara Container

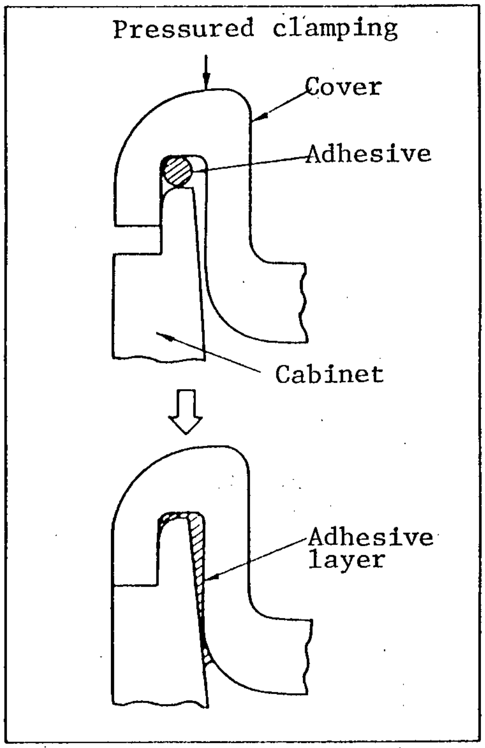

Figure 19. Bonding Example of Foamed Polyethylene of Speaker

Furthermore, it has been made a matter of common knowledge conventionally that plastic acquired a cost advantage in assembly by performing solid molding. However, when the needs of many varieties in small quantity come into the open as seen recently, cases will increase where it will be more efficient to produce low-cost parts with a higher function by means of reducing the die cost and improving productivity (miniturizing of dies, disuse of split dies and cutting dies) or bonding and compounding of molding parts by making the most of various molding materials and molding methods. In showing such examples, the bonding assembly of the extrusion molded PP hose with the injection molded nozzle (7.5 places/minute), the bonding assembly of the PE blow molded main body with injection molded cap and nozzle parts of the automobile gasoline tank, the bonding assembly of the PMMA and PC-made lenses with the ABS, PP- and BMC-made housings of the automobile head and taillights, the bonding of PMMA with ABS and PP of the meter case, and the airtight bonding of nylon with aluminum and brass of the radiator tank can be listed.

Other practical uses and applications that can be considered in the automobile industry are the bonding of the plastic trim panel (SMC, nylon, ABS/PC alloy, etc.), radiator grill (ABS, PP, etc.), instrument panel, and console box (ABS, PP, etc.), battery case (ABS, PP), tanks such as the reserve tank and washer tank (PP, etc.), cases of various parts of the engine mountings (nylon, PBT, PP, etc.), and interior finish materials (PP, PVC, etc.).

In the electricity and electronic fields, the bonding of the housing of computer disk drives and speaker cabinets has been put to practical use and it is believed that it can be used for the housing of other equipment (PP, ABS, PS, PVC, etc.) and assembly of various parts (PP, POM, PBT, etc.). In relation to containers and sundries, it can be used for wide applications such as bonding the top and bottom of plastic cans, for polyolefin-made containers, for cosmetic containers, beer and soft drink containers, adhesive containers, disposable lighters, stationery, writing pens, toys, knobs and handles of furniture (PP/wood), portable urinals, and for musical instruments.

The internal-heat-generating bonding method has been introduced centered around the electromagnetic bonding system. In Japan, development of the application of this bonding method has just started. However, great expectations are placed on its future development as a structural bonding means of polyolefin, engineering plastics, and composite materials through its rationality and mass productivity by quick-bonding.

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FY 87 INTERNATIONAL R&D COOPERATION POLICIES, BUDGET

Tokyo JITA NEWS in Japanese Dec 86 pp 10-15

[Excerpts] 1. International Research Cooperation

International cooperation in research and development will contribute both to the efficient implementation of R&D in Japan, and to harmonious foreign economic activity.

In particular, international research cooperation in advanced industrial fields is becoming more and more important and necessary against a backdrop of recent hopes for activation of the world economy through technological innovation, increasing hopes and demands for Japanese contributions to R&D in the field of advanced industrial technology, and demands that trade friction be avoided.

From that perspective, Japan has for some time sponsored or participated in international conferences, implemented joint research, and participated in joint projects of international organizations. These activities have focused on energy-related R&D. Present multilateral cooperation includes the International Energy Agency (IEA) and followup to summit projects. Bilateral cooperation is carried out under such things as the Japan-U.S. agreement on energy R&D cooperation, the Japan-France and Japan-West Germany agreements on scientific and technical cooperation and the Japan-Australia energy R&D consultations. Japan intends to continue active development based on the results of these arrangements.

The Williamsburg summit reached agreement on 18 cooperative projects which have been actively promoted by the Agency of Industrial Science and Technology [AIST]. At the Tokyo summit held in May, it was decided to terminate cooperative projects within the summit framework and go ahead with independent cooperation, as necessary, on individual projects.

Also, so that R&D on research topics of international importance can by divided up among the advanced industrial countries, the International Specified Joint Research Program was started in 1985, and has worked to promote fundamental international cooperation.

Japan-South Korea S&T cooperation (S&T cooperation agreement
Preparation of base for international research cooperation (program for promotion of LDC industrial technological development)

In the case of the developing countries, joint research is done with LDC's, international symposiums are held, researcher exchanges are conducted and so on in order to promote cooperation on R&D in the field of mining and manufacturing technology, for which there have been strong demands from the LDC's. This has been done in the form of ITIT projects. In addition, Japan has promoted R&D cooperation projects as research cooperation in the stage near to commercialization, it has established local pilot plants for research projects an LDC could not pursue by itself, and it has expanded the commissioning of research cooperation promotion to carry out joint, revolving research. In these ways Japan has tried to carry out comprehensive research cooperation projects.

Budget overview (advanced countries) (unit: million yen)

Item	FY1986 Budget Amount	FY1987 Budget Request	Note
International Technical Exchange	74	98	G
(International Specified Joint Research Program)	35	59	
Japan-Australia S&T Cooperation (coal liquefaction and Sunshine Project funding)	12,992	8,088	S
International Industrial Technology Development Promotion (International Trade Administration Bureau funding)	34	32	G
Projects for international cooperation among summit countries			
Solar power (Sunshine Project funding)	7,467	7,164	G,S
Hazardous Environ. Robots (Large-scale project funding	2,405	2,548	G,S
International Cooperation for Energy Technology R&D (Sunshine and Moonlight Project funding)	98	95	G

Notes: G-- General Account Budget
S-- Special Account Budget

Budget overview (developing countries) (unit: million yen)

Item	FY1986 Budget Amount	FY1987 Budget Request	Note
International Industrial Technology Development Promotion (International Trade Policy Bureau funding)	178	188	G
R&D Cooperation Project Subsidies (International Trade Policy Bureau funding)	53	139	G
Research Cooperation Promotion Commissioned Projects (International Trade Policy Bureau funding)	490	491	G
LDC Research Cooperation Projects (International Trade Policy Bureau funding)	--	176	G
LDC Research Cooperation Project Basic Survey Commissions (International Trade Administration Bureau funding)	35	35	G
LDC Industrial Technology Development Cooperation Promotion (International Trade Administration Bureau funding)	8	7	G

Note: G-- General Account Budget

2. Research cooperation with advanced countries

Considering the major role that technological innovation, particularly in the advanced countries, played in the global high growth of the 1960's, there has been increased interest in research and development of industrial technology as a means to escape from the continuing economic stagnation which has followed the oil crises. With that background, the countries of Europe, Canada, Australia and others have actively approached Japan and requested expansion and intensification of R&D cooperation.

In the past Japan has enjoyed high growth by using imported technology, but it is already reaching the limits of import dependence. Development of advanced industrial technology from these seeds has become indispensable, and basic breakthroughs are especially necessary in fields like new materials, biotechnology and devices. Thus Japan has decided to actively promote international cooperation, and to deal with these problems both through bilateral cooperation with advanced countries and through multilateral cooperation in organizations like the IEA.

A. International Specified Joint Research Program

(1) Purpose of the program: The purpose of the International Specified Joint Research Program is to divide research topics with international importance among the laboratories under the umbrella of AIST and research institutions in foreign countries, to implement joint research on topics where R&D is appropriate, to thus promote efficient and effective experimental

From the perspectives of actively promoting international R&D cooperation focused on the field of basic technology, of raising the level of technology in Japan itself, and of contributing to global scientific and technical progress and economic development, Japan has decided to create a Japan Trust for International Cooperation using funds volunteered by the private sector, and to carry out projects such as inviting foreign researchers to Japan.

Outline of Measures for International Research Cooperation (AIST-related)

(Research cooperation with advanced countries)
- Summit-related multilateral cooperation
- Multilateral cooperation with the International Energy Agency (IEA)
  - Committee on Energy Research & Development (CRD)
- Bilateral cooperation
  - Japan-U.S. S&T cooperation (energy R&D cooperation agreement, non-energy cooperation agreement (UJNR), environmental protection cooperation agreement)
  - Japan-Australia S&T cooperation (energy R&D consultations, S&T cooperation agreement)
  - Japan-Canada S&T cooperation (S&T cooperation consultations, S&T cooperation agreement)
  - Japan-New Zealand S&T cooperation
  - Japan-France S&T cooperation (S&T cooperation agreement)
  - Japan (AIST)-Sweden (STU) S&T cooperation
  - Japan-Britain S&T cooperation
  - Japan-EC S&T cooperation
  - Japan-Italy S&T cooperation
  - Japan (AIST)-Finland (TEKES) S&T cooperation
- International Specified Joint Research Program
- Preparation of base for international research cooperation (program for promotion of international industrial technological development)
- Japan Trust for International Research Cooperation

(Research cooperation with developing countries)
- Institute for Transfer of Industrial Technology research (ITIT projects)
  - International research cooperation program (special research, transfer research, development research)
  - Overseas technology research coordination program
  - Researchers exchange activities program (invitation of research officials, special researcher invitation system, acceptance of graduate students)
  - International symposium program
  - (International joint research cooperation program)
- Program to commission promotion of research cooperation
- Research and development cooperation assistance program
- UN, ESCAP, other multilateral research cooperation
  - Coordinating committee for joint survey of Asian coast mineral resources
- Bilateral research cooperation
  - Japan-PRC S&T cooperation (S&T cooperation agreement
  - Japan-Indonesia S&T cooperation (S&T cooperation agreement
  - Japan-Brazil S&T cooperation (S&T cooperation agreement
  - Japan-India S&T cooperation (S&T cooperation agreement

research, and to appeal to other countries with Japan's international contributions. The amount requested for this program in the 1987 budget is 59,044,000 yen.

(2) Framework of research development: Joint research with a definite division of roles between foreign laboratories and Japanese laboratories will be carried out on R&D problems where the research content and capabilities of two sides are complementary. Researchers will be exchanged, but each institution will be responsible for costs of its own researchers. The conduct of joint research (research objectives, time period, ownership of results etc.) will be decided in consultations between the laboratories working on each R&D topic. For the present, the cooperating institutions will those under the control of national or local governments, or equivalent institutions.

International Specified Joint Projects for FY1987 (proposed)

a. Research on synthesis and structural defects of anion-doped quartz glass: This glass is used as material for optics (optical fiber, glass lasers) and electronics (insulating layers in IC's). Research is to include structural defects in the glass material and weaknesses of its products, and synthesis of anion-doped quartz glass which may have fewer structural defects. The project is to last five years beginning in 1985. The cooperating institutions are Japan's Electrotechnical Laboratory (to take up synthesis of anion-doped quartz glass by optical CVD [chemical vapor deposition]) and France's Saclay Atomic Energy Laboratory (measurement and analysis of defects in such glass).

b. Research on ultrasensitive sensing technology using high-stability lasers: This project is to develop extremely precise control of the laser wavelength, and technology for ultrasensitive detection using the laser's absorption and dispersion characteristics and information at the atomic and molecular level from various chemical reactions and nuclear fusion plasma. The project is to last five years beginning in 1985. The cooperating institutions are Japan's National Research Laboratory of Metrology (development of high-performance laser beam-splitting technology) and West Germany's Institute of Physics and Engineering (research on selective stimulation of atoms and molecules, and examination of the state of unstable molecules).

c. Development of refractory carbon-ceramic compound materials and research on their high-temperature characteristics: This research is to clarify the high-temperature characterists of carbon-ceramic compound materials capable of machine processing, study the conditions for compounding carbon with ceramics, and develop a structural material with superior heat resistance. The project is to last four years beginning in 1986. The cooperating institutions are the Government Industrial Research Institute in Kyushu (development of refractory carbon-ceramic compound materials) and West Germany's Air and Space Institute (explication of high-temperature characteristic of such materials).

d. Research on optical micro gas sensors: This research is to develop an optical gas detector element which will detect the density of gas using light beams and transmit sensor data in optical form, and to contribute to the development of highly reliable, miniature gas sensors which are non-explosive and noise-resistant. The project is to last four years beginning in 1987. The cooperating institutions are the Government Industrial Research Institute in Osaka (trial manufacture of optical micro gas sensors) and Belgium's Leuven Catholic University (gas sensing surface and characterization of junction boundary).

e. Research on water permeability of discontinuous surfaces in bedrock and technology for evaluation of safety: This is to be experimental research on the mechanical strength of discontinuous surfaces in bedrock and changes in water permeability in fissures. It is to establish a method for evaluation of these discontinuous surfaces and contribute to development of underground storage technology for subterranean disposal of waste products. The project is to last five years beginning in 1987. The cooperating institutions are the Geological Survey of Japan (analysis of fracture development using AE seismograph, and explication of water permeability using precision measurement of elastic wave velocity) and the U.S. Geological Survey (experimental measurement of water permeability of discontinuous surfaces in bedrock, and measurement of water permeability of low-permeability bedrock using subterranean model experiment).

B. Japan Trust for International Research Cooperation

(1) Program goals: This program is to actively promote international research cooperation, primarily in the field of advanced technology, thus raising the level of technology in Japan itself. Moreover, from the perspective of contribution to progress in world scientific technology and development of the world economy, Japan will create the Japan Trust for International Research Cooperation, using funds voluntarily contributed by the private sector, and conduct projects such as recruiting researchers from abroad.

C. Active promotion of summit-related international research cooperation projects: Solar generation of electricity and advanced robotics are international research cooperation projects begun on the basis of agreement at the Williamsburg Summit. Japan will actively promote these, while maintaining close contact with the other participating countries.

D. International cooperation for energy technology R&D: Japan intends to actively participate in R&D cooperation under IEA, and to enhance international cooperation for energy technology R&D in such forms as expansion and intensification of Japanese-Australian cooperation on coal liquefaction.

E. Promotion of program for promotion of international industrial technological development: In order to carry out international cooperation in the field of advanced technology, as a part of the Industrial Cooperation and Technological Exchange Center established (under JETRO) in 1983, Japan will implement such things as consulting and feasibility studies for international joint R&D (including invitations to technical personnel, and will actively

promote basic preparations for international research cooperation.

F. Promotion of international technical exchange: Such things as participation in international conferences, information exchanges and the sending of experts will be carried out on the basis of bilateral S&T cooperation agreements

Setup for Japan Trust for International Research Cooperation

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|--------------------------------------|
|              Trust Bank              |
|                                      |
|  |--------------------------------|  |
|  | Japan Trust independent form   ---- Contributor
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|  | Japan Trust recruitment form   --|- Contributor
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        |                |       |
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| Japan Key Technology Center |  (d)    |    Guest    |
|                                 Researchers |
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(a) Subsidies
(b) Permits and supervision
(c) Applications and notifications
(d) Subsidy support

3. Research Cooperation with Developing Countries

Developing countries have numerous R&D topics to contribute to their own economic and social development, and they expect much of research cooperation from Japan, with its high R&D potential.

Research cooperation is not mere technology transfer. Its execution promotes research and heightens the research capability of the developing country. It is extremely effective cooperation in that it has the effect of enabling autonomous development at the hands of the developing country itself.

To meet the strong need of the developing countries for this sort of research cooperation, cooperation is carried out at the laboratory level by the ITIT. Such projects include commissioned projects to promote research cooperation which carry out revolving research with the results used in pilot plants, and R&D cooperation assistance projects which carry out research at the demonstration plant level.

A. Institute for Transfer of Industrial Technology (ITIT projects): These projects have been carried out since 1973 in order to implement research cooperation in the mining and manufacturing technology field which is of greatest interest to developing countries, while systematically utilizing the research potential of the research laboratories of AIST, and thus to contribute to the training of research personnel and the upgrading of research capabilities in the developing countries. The program has grown ever since; from FY1973 to FY1985 the amount budgeted grew from 36 million yen to 178 million yen, the number of projects from 4 to 23, and the number of exchange researchers from 12 to about 58. A total of 84 projects (including those now underway have been implemented).

In FY1984 joint projects were begun with a number of new developing countries, and an new system of inviting special researchers was instituted. And an International Joint Research Cooperation program, in which Japan and other advanced countries will join in cooperating with developing countries, is to be implemented starting in 1987.

Programs are outlined below.

(1) International Research Cooperation projects: These are projects in which joint research is carried out by AIST research laboratories and research laboratories in developing countries. Joint research is carried out both by sending Japanese researchers to the other countries, and by inviting their researchers to Japan.

(a) Special research: This research follows the directions set by AIST research laboratories, but research projects are selected in accordance with the social demands of the developing country. The joint research is carried by an AIST research laboratory and a research institution of the cooperating country.

(b) Transfer research: It is often difficult for technology existing in Japan to take root and grow when it is transplanted to the strange soil of a developing country. Thus joint research is conducted encourage effective technology transfer and to make technology transfer more efficient by answering the question of what improvements and considerations are necessary to encourage effective technology transfer and promote the growth of the transferred technology.

(c) Development research: This research is to systematically analyze such things as mineral resources, plant resources and infrastructure for industrialization, in order to use the developing country's products effectively. Expansion of potential uses is considered, and the seeds of future special research and transfer research are sought.

(2) Overseas technology research coordination program: These include participation in international conferences and on-site studies in search of research topics considered necessary in the developing country and possibilities for future research cooperation projects

(3) Researchers exchange activities program:

(a) Invitations to research managers: By means of inviting research managers from developing countries, this project is to create opportunities to discuss the present status of laboratories, research methods and R&D, and thus deepen mutual understanding. This is expected to effectively promote research cooperation.

(b) Invitations to special researchers: This project will intensify research exchange by making long-term invitations to researchers of developing countries who have achieved superior results in R&D fields which are needed by developing countries. This will contribute to enhancement of the research level of the developing countries.

(c) Acceptance of trainees and assignment of experts: Trainees will be accepted and experts will be sent on the basis of cooperation with international organizations and the Japan International Cooperation Agency (JICA).

(4) International symposium program: Since sponsoring the "International Symposium on Desalination and Reuse of Water" in 1977, Japan has convened international symposiums on "Standards of Measurement," "Solar Thermal Energy," "Metal Ore Deposits of the Asian Region," "Industrial Uses of Tropical Vegetation," "Standards of Measurement in Developing Countries," "Evolution of the Earth's Crust, Resources and Geologic Disasters" and "Resource Development and Prevention of Pollution," followed in FY1984 by "Standards of Measurement (Qualitative and Relative)" and in FY1985 by "Status and Prospects for International Research Cooperation." In FY1986 a symposium was held with the topic "Industrial Uses of Biomass and Bioenergy."

(5) International joint research cooperation program:

(a) Program goals: This program is to take advantage of the R&D potential of the advanced countries to deliver effective research cooperation to the developing countries, by jointly and directly carrying out research cooperation, having specified advanced countries divide up costs and fields of cooperation on research topics which meet the needs of developing countries.

(b) FY1987 project: Research on development of technology for prospecting for rare and urgently needed mineral resources.

(c) Research institutions: The AIST laboratory is the Geological Survey of Japan. The cooperating research institutions are the Philippines Mining and Earth Sciences Bureau and the U.S. Geological Survey.

(d) Outline of research: Research cooperation is to be provided for the purpose of developing new mineral deposit prospecting technology (for such

minerals as gold, platinum and chromium) suited to the geology of the Philippines, making use of Japan's mineral deposit prospecting technology and America's technology for prospecting for chromite and platinum ores. The project is to last five years beginning in 1987.

B. Program to commission promotion of research cooperation: Developing countries have many R&D topics which would contribute to their development, and they expect much research cooperation from Japan, which has high R&D potential. Research cooperation is not mere technology transfer. Its execution promotes research and heightens the research capability of the developing country. It is extremely effective cooperation in that it has the effect of enabling autonomous development at the hands of the developing country itself.

To meet the strong need of the developing countries for this sort of research cooperation, coordinated research cooperation will be implemented for research topics on which the basic research has been completed but which involve numerous R&D elements which the developing countries are unable to carry out by themselves. In such cases, pilot plants will be set up within the developing countries and guidance will be given the researchers of the cooperating countries to accomplish joint, revolving research.

C. Program to assist R&D cooperation: Research cooperation will be carried out under ITIT projects or the program to commission promotion of research cooperation; this will be at the demonstration plant level, when the technology is close to realization. There are thus three stages: (a) basic research, (b) research at pilot plant (program to commission promotion of research cooperation); and (c) demonstration plant (program to assist R&D cooperation).

D. Program to promote cooperation for development of industrial technology in developing countries: In order to actively support development of industrial technology in ASEAN and other developing countries, to raise the research potential of developing countries, and to contribute to harmonious trade with developing countries, the functions of JETRO will be used to implement such projects as consulting, surveys of research cooperation needs, and seminars on dissemination of the fruits of research cooperation carried out by AIST.

E. Promotion of international technical exchanges: Such things as participation in international conferences, information exchanges and the sending of experts will be carried out on the basis of bilateral S&T cooperation agreements

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RECENT DEVELOPMENTS IN ARTIFICIAL ORGANS DISCUSSED

Tokyo SENSOR GIJUTSU in Japanese Aug 86 pp 53-58

[Article by Makoto Kikuchi and Naoki Negishi, National Defense Medical College: "Status of and Recent Progress in Biochemical Instrumentation"]

[Text] To begin, let us define what artificial organs are: Artificial organs are devices which perform the functions of vital organs or have their forms as artificial organs and are designed for treatment. These treatment-purpose artificial organs can be divided by the degree of their functional substitution as seen in Table 1. These artificial organs differ from artificial intelligence in the information engineering sector and the rehabilitation engineering sector for electric upper extremity prostheses, etc., targeted at external physical disturbances in that they are regarded as a means of treating internal physical disturbances.

Studies of artificial organs are being advanced from the substitution of partial to entire function, from temporary to long-term use and, in terms of form, toward compactness, portability, and self-containment. Parallel to this, problems of instrumentation and control will become important, thereby resulting in sophisticated functions of artificial organs. However, viewed as instrumentation control equipment, artificial organs pose a number of problems, such as intrinsic measurand control often unclear, necessary instrumentation at times impossible, and intrinsic quantity control often unclear or impossible to be measured.

The vascular wall of an organism, for example, seems to be provided with a mechanism to sense flow rate: experiments have confirmed that anastomosis of a dog's carotid artery and vein produces a thick short circuit path between them, and the blood vessels become thicker in a few weeks as blood flow increases with the shear stress value of the blood vessels' internal wall which remained constant.[1]

Artificial blood vessels shown in the first group of Table 1 have durability, flexibility, and antithrombotic capability to some extent, while they do not have sensors to sense flow rate stress or functions to change the vessel shapes, which is difficult to materialize artificially. In addition, chemical information is related to responses of an organism, so that the more sophisticated the functional substitution by an artificial organ is, the more necessary instrumentation of biochemical quantity, as measurands, becomes.

Table 1. Classification of Artificial Organs by Control Information System*

Group	Information level	Information quantity	Features and examples of artificial organs
1st	(PI) (CI) (BI)	--	Provide mechanical support. It is important to develop artificial materials to meet their bio-adaptability along with their medical functionality. Currently information for systematization is not considered. Examples: Passive element type artificial organs such as artificial blood vessels, bones, and valves.
2d	PI (CI)	Small	Partial functions are substitutive for a short period of time. Examples: Active system type artificial organs requiring an energy source such as an hepatic function auxiliary device and an artificial heart-lung.
3d	PI CI	PI: Large CI: Small	Large in size, used outside the body, aimed at long-term substitution. Examples: Material transfer-related active system type artificial organs requiring energy and information such as artificial kidney, artificial lung, and auxiliary heart.
4th	PI CI (BI)	PI: Large CI: Small or CI: Large PI: Small	Portable or of organism-built-in type, aimed at long-term use. Examples: Active system type artificial organs requiring physical information, such as heart and urinary bladder pacemakers; passive system type ones requiring chemical information closely related to the drug transmission system of the pharmaceutical area such as a portable artificial kidney, artificial pancreas and blood.
5th	PI CI (BI)	Large	Organism-built-in type, aimed at long-term use. Examples: Highly active system type artificial organs provided with a chemical control function requiring biochemical information as well as physical information, such as an artificial pancreas, fully artificial heart, fully artificial liver, fully artificial kidney, and artificial cells.

*Classification by the quantity and level of information for bioinstrumentation. The higher the degree of functional substitution by an artificial organ is, the larger the quantity of necessary information becomes. The types of information

[continued]

[Continuation of Table 1 note]

obtained are physical information (PI), chemical information (CI), and biological information (BI) in ascending order of their levels. In addition, it has been assumed that the longer the service duration of artificial organs is, the higher the information quantity necessary and its level become, respectively.

For example, the control system of a heart includes chemical control by hormones such as adrenalin; therefore, a completely artificial heart will need functions more than a blood pump merely equipped with a drive and a playback device. In addition, a sensor responding to lactic acid will be needed since failure of an artificial heart's drive will cause lactic acid to increase.

At present, parameters are unknown in many cases, which makes it difficult for the relationship between the artificial organ and the sensor which requires clear distinctions. Few artificial organs have a built-in sensor or are fully equipped with an instrumentation system.

Generally speaking, an artificial organ instrumentation system requires a sensor to obtain information on the physiological functions of the organism in order to control the artificial organ and one to monitor whether the artificial organ functions safely for the organism. In addition, as an artificial organ becomes more sophisticated as in the fifth group in Table 1, measurands by the system cover a wider range from physical to chemical quantities.

1. Artificial Organs and Sensors

The development of an instrumentation system for artificial organs needs to meet strict, difficult requirements since, as already stated, what is needed for true measurands of individual artificial organs is not clear, and sensors' bioadaptability and long-term reliability to protect organisms are required. The quantities to be measured vary from physical to chemical to biological. Tables 2 and 3 show the outline of instrumentation for artificial organs for chemical and physical quantities.

Biological instrumentation requires hematological examination such as hemolysis, coagulation, bloodcell volume, number of blood cells and figures, histological examinations of epibolic formation, calcification, encapsulation, and immunological examinations. However, long-term and continuous cellular- and tissue-level instrumentation such as morphological examinations is more difficult than molecular-level instrumentation. The discussion on this kind of biological instrumentation shall be omitted here since at present the specimen examination approach of intermittently extracting specimens from organisms is used as it is.

For sensor technology trends in bioinstrumentation and general aspects of physical quantity instrumentation of organisms, please refer to our explanations.[2,3] Individual explanations of sensors in the area of artificial organs are given by Togawa[4] and Kanai[5]; hereunder an outline of the status quo of

biochemical instrumentation which is likely to be important as a sensor for artificial organs in the future, including its recent progress is given.

2. Biochemical Instrumentation

Clinical examinations are divided into organism examinations (patient examinations) and specimen examinations; physical information from organisms is measured mainly in the former, while biochemical and biological information is measured in the latter. In the case of an artificial organ, it is necessary to measure various aspects of the functioning organism in order to permit the artificial organ to function safely and normally for the organism. In many cases, the chemical quantity to be measured is more important than the physical quantity.

However, the conventional specimen chemical instrumentation method (clinical chemical analysis) is often not suited for artificial organs because instrumentation is made intermittently, hands are needed for extracting specimens, and considerable time must be consumed before obtaining measured results. Besides, the development is desired at present for continuous biochemical instrumentation equipment.

Generally speaking, biochemical instrumentation methods can be largely divided into an electrochemical method using percutaneous electrodes and stylus-type microelectrodes, a radiochemical method using radio isotope (RI), and optical and magnetic resonance methods utilizing absorbed electromagnetic waves. Of them, expectations are placed as a powerful means of unintrusively obtaining biochemical information on positron computerized tomography (CT) utilizing positron emission nuclear species and nuclear magnetic resonance (NMR) spectroscopy utilizing absorption of radiowaves caused by nuclear spin transition in a magneticfield. However, positron CT and the NMR spectroscopic methods need large equipment, thereby necessitating large-scale installations.

Optical measuring methods include those using an ear oximeter to measure the blood oxygen saturation degree in auricular tissues, an ear densitometer to measure changes in pigment concentration of internal blood flow by infusing (indocyaninglean), etc., and a bilirubinometer[6] to measure serum bilirubin concentration from the frontal region; however, the electromagnetic areas of these apparatuses are for visible parts, targeted at limited areas in organisms.

Electrochemical instrumentation methods include those using a pH meter, stylus type microelectrodes, a PCO_2 meter and enzyme-immobilized biosensors, while as a method not using blood, there is one to measure dissolved oxygen partial tissue pressure by percutaneous oxygen electrodes to estimate arterial blood oxygen partial pressure.

Of them, a method using an ultracompact electrochemical sensor provided with an ion or molecule identification function[2] is generally available as a chemical sensor for artificial organs. For example, a study is being made in the development of a built-in tissue chemical sensor to measure blood sugar values in succession using stylus-type microelectrodes on which glucoseoxitase is

Table 2. Chemical Quantity Instrumentation for Artificial Organs

Measurand	Sensor	Artificial organ
PO_2, PCO_2 (blood gas partial pressure)	Oxygen electrode (Clark type: amperometry) Percutaneous O_2 electrode ((Severinghouse) type: potentiometry) Percutaneous CO_2 electrode	Artificial heart, artificial lung, artificial heart-lung, respiration controller
O_2, CO_2 (exhalation gas)	Gaseous phase oxygen densitometer Infrared absorption gas spectrometer Mass spectrometer	Artificial respiratory organ
pH (hydrogen ion concentration)	Stylus-type pH glass micro-electrode (potentiometry) Ultracompact ion sensor (ISFET)	Artificial kidney, artificial liver, artificial heart (blood, body fluid, urine, irrigating fluid)
Electrolyte concentration (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-)	Ion selective electrode ISFET Conductivity meter (for dialysis fluid)	Artificial kidney, artificial liver (blood, body fluid, dialysis fluid)
Lactic acid	Biosensor (lactic acid oxitase: O_2 electrode, amperometry)	Artificial heart
Catecholamine*	Specimen examination (fluorescence method, fluid chromatography)	Artificial heart
Hormone (insulin,* vasopressin, etc.)	Specimen examination (RIA)	Artificial pancreas, artificial heart
Blood sugar value (glucose)*	Biosensor (glucose oxitase: O_2 electrode or H_2O_2 electrode, amperometry)	Artificial pancreas
Urea*	Biosensor (urease: NH_3 electrode, potentiometry)	Artificial kidney
Uric acid	Biosensor (uricase: O_2 electrode, amperometry)	Artificial kidney
Creatinine	Biosensor (creatininedeminase: NH_3 electrode, potentiometry)	Artificial kidney

[continued]

[Continuation of Table 2]

Measurand	Sensor	Artificial organ
Ammonia	Ammonia gas electrode (gas sensitive electrode: potentiometry)	Artificial kidney
Bilirubin	Specimen examination (diazo-method) Bilirubinometer (optical measuring method)	Artificial kidney
Pharmaceutic concentration	Instrument for analysis of multicomponent (fluid chromatography)	Artificial kidney
Miscellaneous internal harmful matter	Fluid chromatography	Artificial liver, artificial kidney (medium molecular-weight matters)

*Recently a study was made of measuring methods by modifier electrodes and biosensors. In addition to the above items, measurements of enzymes, proteins, and cholesterol are necessary. Sensors for measuring their chemical quantities are classified as concentration sensors.

immobilized as a glucose molecule identification element.[2] The stylus-type microelectrode shows a direction for clinical chemical examinations to proceed, from conventional specimen chemical instrumentation to biochemical instrumentation similar to cardiogram measurement.

Generally speaking, to measure specific matter from a system comprised of multicomponent chemical matter-like an organism, either a separative or a molecule identification function to detect chemical signals becomes necessary. A sensor utilizing molecule identification functions existing in the organisms as shown in Table 4 is called a biosensor, while one modified by a synthetic chemical method is called a chemical modifier sensor. Biosensors are being studied as sensors for artificial organs since it is difficult at present to create various identification elements from synthetic matter alone.

As a physicochemical device to detect chemical information, electrodes are most generally implemented with some already put to practical use. Furthermore, a study has been made recently of a semiconductor biosensor[2,9] using an ion sensitive field-effect transistor (ISFET), anticipating the development of a biochemical IC permitting simultaneous instrumentation of various kinds of chemical matter.

Direct measurement of a biosensor in blood, however, causes protein, etc. to be adsorbed on a biofunctional film of its molecule identification part, thereby posing the problem of a rapid decrease in the sensitivity of electrochemical sensors. We have developed a percutaneous suction method of obtaining biobody fluid as biochemical information responding to blood. We have reported that with high molecular weight matter, the decoction obtained by

Table 3. Physical Quantity Instrumentation for Artificial Organs

Measurand	Sensor	Artificial organ
Pressure (blood pressure, drive pressure, osmotic pressure)	Diaphragm type pressure intensifier Electric sphygmomanometer (wire strain gauge, semiconductor strain gauge) Differential pressure gauge using magnetic resistance changes Osmometer	Artificial kidney (blood pressure, ultrafiltration pressure, blood plasma osmotic pressure) Artificial heart (atrium pressure, arterial pressure, drive air pressure) Artificial lung (range between artery and vein) Artificial respiratory organ (respiratory tract internal pressure, pleural cavity internal pressure)
Flow rate, flow velocity (flow rates of blood, gas, matter)	Electromagnetic flowmeter Supersonic flowmeter (Doppler shift method, propagation time difference method) Air flowmeter (supersonic type, Karman's vortex type, thermal pulse type) Stroke sensor	Artificial kidney (blood flow rate, dialysis fluid flow rate, dehydration volume) Artificial heart (cardiac output, cardiac stroke) Artificial pancreas (infusion volume of drugs such as glucose and insulin) Artificial lung (blood flow rate, gas flow rate) Artificial respiratory organ (gas flow rate)
Electric potential	Induction electrode	Heart pacemaker (R-R time of cardiac rhythm)
Temperature (body surface--deep temperature, blood temperature)	Thermistor thermometer (heat flow rate compensating method) Resistance thermometer	Artificial kidney (body temperature, blood temperature) Artificial heart (body temperature, blood temperature) Artificial lung (body temperature, blood temperature)
Miscellaneous	Bubble detector Blood leakage sensor Thrombus detector Weight measuring instrument	Artificial heart (number of heartbeats, blood leakage, bloodclot, urine volume)

Table 4. Main Molecule Identification Functional Matter[8]

Molecule identification functional matter	Matter to be identified	Stability of complex
Enzyme	Substrate, substrate analog	Transient
	Coenzyme	Stable
	Inhibitor	Stable
Antibody	Antigen, hapten	Stable
	Complement	Transient
Lectin	Sugar, sugar residue	Stable
Combined protein	Biotin, retinal, etc.	Stable
Hormone receptor	Hormone	Stable
Ring peptide antibiotics	K^+, etc.	Stable

suction is about half as low as its blood concentration in protein, while with low molecular weight matter such as glucose, it is almost equal to its blood concentration.[10,11] We have currently proposed a new biochemical instrumentation method combining the suction decoction obtaining method with a semiconductor biosensor. Its study is underway.

Togawa and his colleages[4] have developed a hollow fiber-applied monitor system for blood gas and pH in external circulation, while J.S. Schultz, et al., have also proposed an interesting glucose biosensor utilizing hollow fibers.[12] It is a system involving the immobilization of concanavalin A (Con A), a lectin protein, within a hollow fiber as a molecule identification element, sealing within it fluorescence-labeled dextrans which combine competitively with gluclose, and are optically measured by an optical fiber system. Dextrans combine with Con A at a constant rate, while in glucose solution, Con A also combines with glucose, thus resulting in an increase in the number of free dextrans, by optical measurement of which glucose concentration can be obtained.

Controlling artificial organs requiring real-time on-line measurement makes biochemical instrumentation for artificial organs largely different in specifications from conventional specimen chemical instrumentation. The former's ideal purpose is long-term continuous measurement, while it is of great worth in short-term use similar to an intensive care unit (ICU) for use in emergency and surgical operations. For example, blood sugar value management for patients who have undergone total replacement of their pancreases is an important problem, so that a glucose sensor will play a great role as a postoperative management device.

Generally speaking, the development of sensors for artificial organs has great significance even if their long-term use is difficult at the moment. This

limited space does not allow us to discuss matter related to hybrid type artificial organs and the drug transmission system; bioinstrumentation of specified local information in the future will cover not only physical but chemical and biological information. As to biological information, a study was already made of a biosensor capable of recognizing a lymphocyte B cell, expected to progress in the future.

FOOTNOTES

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